WIN HEADPHONES WORTH **£149**

RADIOACTIVE POWER
Fuelling space robots to explore other worlds

HOW IT WORKS

FEATURING LIVESCIENCE

THE MAGAZINE THAT F

DEADLY PARADISE
Exploring Bolivia's beautiful but dangerous Madidi Park

REVEALED

HOW TO SURVIVE IN THE ARCTIC

WHY BIRDS EVOLVED BEAKS

WE GO INSIDE A MONEY FACTORY

HOW YOU COULD BE CLONED
What it takes to make copies of living things

IMPACT EARTH!

HOW MASSIVE METEORITES MADE HUMANKIND
PLUS THE PLAN TO SAVE OUR WORLD FROM EXTINCTION

FLYING MACHINES
Discover the wacky way helicopters take to the skies

+ INSIDE THE NEW MACBOOK AIR

YOUR CURIOUS QUESTIONS ANSWERED

FUTURE
ISSUE 122

DOWNLOAD
THE DEMO GAME
FOR FREE!

THE CARD GAME INSPIRED BY ESCAPE ROOMS!

Embark on great adventures, search scenes for clues, combine objects and solve puzzles - with only one hour on the clock! Each of these three new adventures captures the pulse-pounding excitement and devilish riddles of an escape room and brings it to your tabletop!

WELCOME

The magazine that feeds minds!

In 2014, Mars had a very close call with a comet called Siding Spring. If it had impacted the Red Planet, this vast ball of rock and ice would have released energy equivalent to thousands – if not millions – of Hiroshima atomic bombs. On Earth, we've never observed a close call with an interplanetary leviathan of this magnitude in recorded history, though there's plenty of evidence of even bigger impacts across our world in the form of ancient craters that date back billions of years. These massive meteorites weren't just responsible for destruction; some of them cleared the way for new life and ultimately the evolution of humankind. On page 22, read about these ancient impacts, the cataclysmic events they caused, the technology we use to detect and track near-Earth objects and how we might protect our world from a future disaster.

Ben Biggs
Editor

"Meteorites were repeatedly slamming into the surface"

Impact Earth, page 22

Meet the team...

Charlie G
Production Editor
I hate the cold, so I can only admire the brave souls on page 74 who raced to the poles. On a less icy note, this is my last issue of **HIW**. Bye!

Baljeet
Research Editor
A crater discovered below the Hiawatha Glacier is the first to be found under an ice sheet. Find out more about it on page 22.

Charlie E
Staff Writer
How – and why – do scientists make exact copies of living individuals in the lab? Find out in our cloning feature on page 56.

Scott
Staff Writer
Madidi National Park is one of the world's most diverse environments. Dare you explore this beautiful but deadly paradise on page 36?

Duncan
Senior Art Editor
It's incredible to think how much goes into making our money. Find out just how your loose change and plastic notes are made on page 64.

FOLLOW US... How It Works magazine @HowItWorksmag

CONTENTS

MEET THIS ISSUE'S EXPERTS...

James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.

Jo Stass
Jo has been a writer and editor for over six years. She is particularly interested in the natural world and technological innovations.

Jodie Tyley
The former Editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.

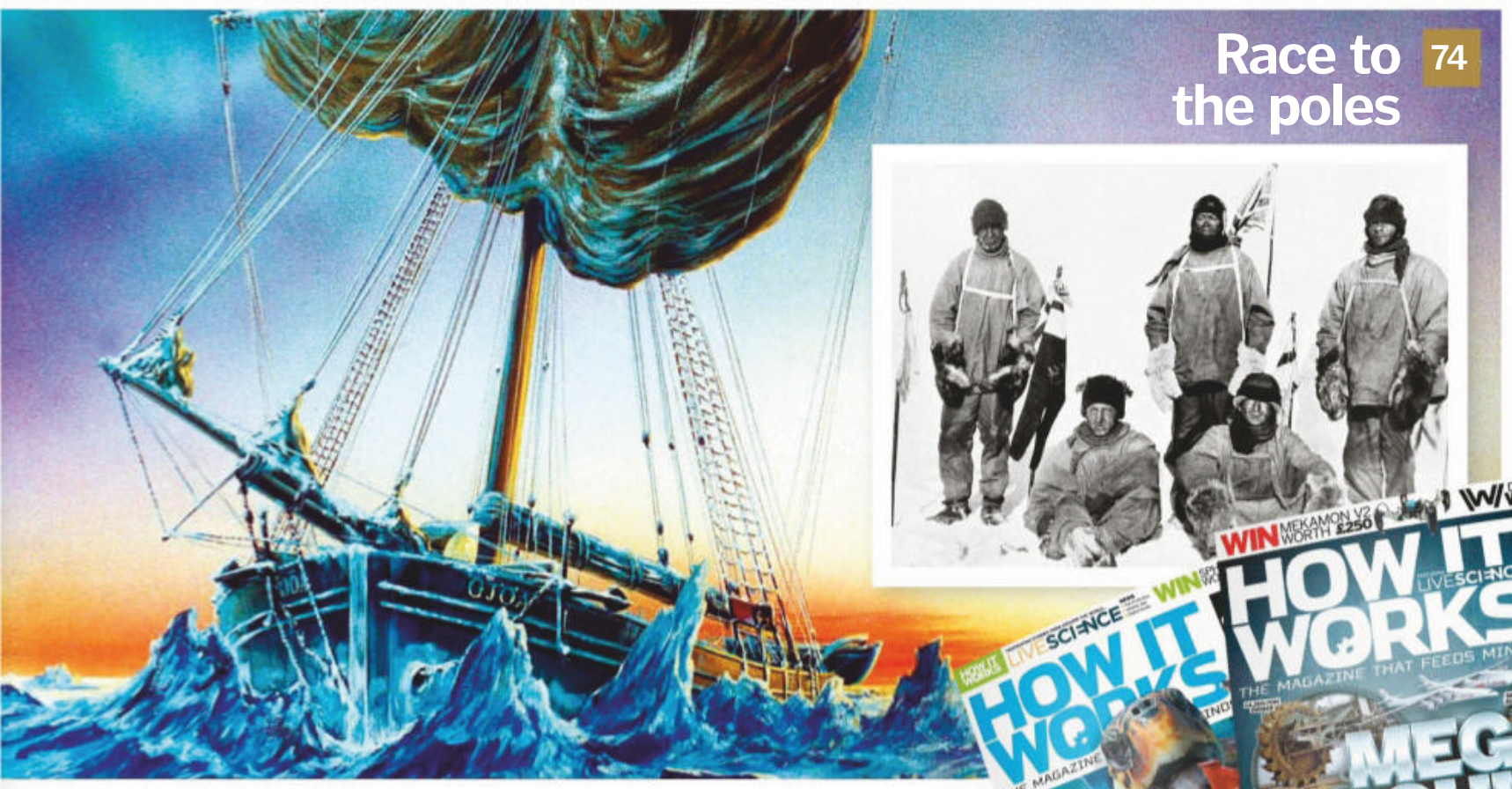
Jonathan O'Callaghan
With a background in astrophysics, former **HIW** and **All About Space** journalist Jonathan enjoys delving into the wonders of space.

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.

Stephen Ashby
Stephen has been a writer and editor for over seven years. He is endlessly intrigued by technology and Earth science.

Steve Wright
Steve has worked as an editor on many publications. He enjoys looking to the past, having also written for **All About History** and **History Of War**.

Tim Williamson
History Of War
Editor Tim has a passion for all things military but studies and writes about a range of historical eras.



REGULARS

Tom Lean
Tom is a historian of science at the British Library working on oral history projects. His first book, *Electronic Dreams*, was published in 2016.

Victoria Williams
Evolutionary biologist and former **World of Animals** writer Vicky is fascinated by nature and happiest when outdoors.

Manta ray's krill buffet

It's dinner time for this manta ray as it looms out of the depths to feed upon a vast shoal of krill and plankton. Krill are tiny shrimp-like crustaceans found in oceans worldwide and form the staple diet for many larger ocean-dwelling animals. They are a key prey animal and have a biomass of nearly 400 million tons in Antarctica's Southern Ocean alone. As the oceans have warmed with climate change some species of krill have retreated south, which will have a negative impact further up the food chain in the long term.

Super blood wolf Moon

Late January 2019 saw the rise of a special type of lunar eclipse. The first 'supermoon' of this year (when the Moon is at its closest point to the Earth and looks larger in the sky) coincided with a 'blood wolf Moon' (a total lunar eclipse). It appears red because, although the Earth's shadow is passing across the Moon, longer wavelengths of sunlight are refracted around the edges of the Earth by our atmosphere, giving the Moon an eerie red glow.

The 1-trillion-star galaxy

Around 55 million lightyears from Earth, in the Coma Berenices constellation, is Messier 100, a well-defined spiral galaxy that's 167,000 lightyears wide, roughly 1.5 times the size of the Milky Way. Messier 100 was discovered in 1781, and was one of the first objects that the Hubble Space Telescope focused on when it launched in 1990. Since then, servicing missions and upgrades have vastly improved the quality of Hubble's imagery. This is the most recent photo of the galaxy, taken by Hubble's Wide Field Camera 3.

GLOBAL EYE

Showcasing the incredible world we live in

IN ASSOCIATION WITH

LIVESCIENCE

With over 14 million global monthly users, **Live Science** makes every day a little more interesting by illuminating the fascinating world around us. For the science geek in everyone, **Live Science** breaks down the stories behind the most interesting news and photos on the internet.

HISTORY

King Tut's tomb finally restored

The north wall of the burial chamber of the tomb of Tutankhamun in the Valley of the Kings

Words by **Megan Gannon**

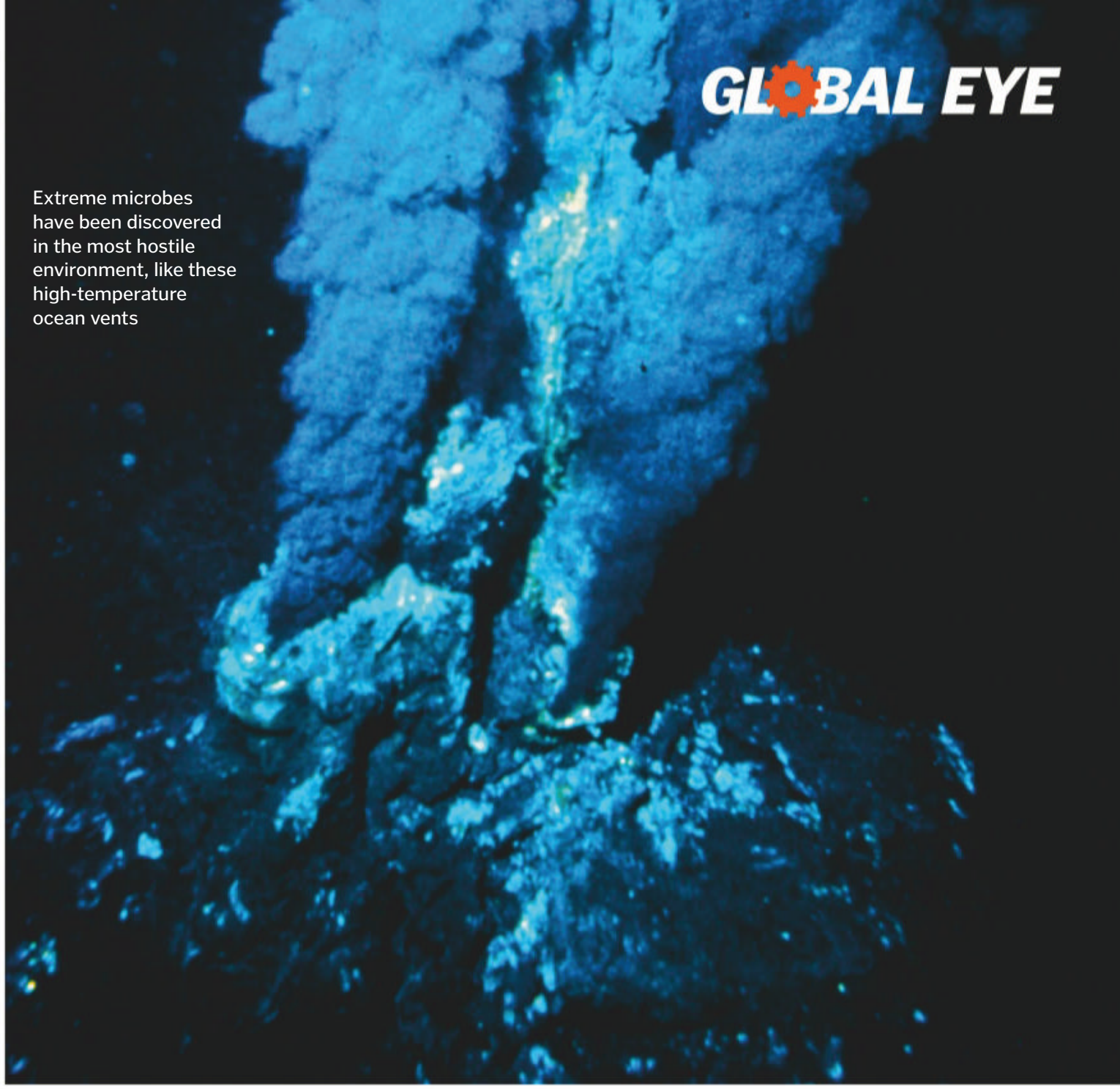
Conservationists have finally completed a decade-long restoration of the tomb of King Tutankhamun in Egypt. The project – carried out by the Los Angeles-based Getty Conservation Institute (GCI) and the Egyptian Ministry of Antiquities – involved stabilising the wall paintings that decorated the 3,000-year-old tomb, as well as adding features like new barriers and a new ventilation system that would reduce damage to the site in the future.

"Conservation and preservation is important for the future and for this heritage and this great civilisation to live forever," Zahi Hawass, an Egyptologist and the former minister of State for Antiquities in Egypt, said in a statement.

Tutankhamun was born during Egypt's New Kingdom in around 1341 BCE. Sometimes called the boy king, he began his rule at the age of nine and died suddenly in his late teens. His tomb became world famous in 1922 when British Egyptologist Howard Carter found the site in pristine condition. While many other royal tombs in Egypt's Valley of the Kings had been pilfered in antiquity, Tutankhamun's burial chamber was discovered intact thanks to mud and rocks that blocked the entrance.

Carter's team spent ten years removing artefacts from the richly packed tomb. After their investigation the site became a major tourist attraction. But visitors bring dust as well as changes in humidity and carbon dioxide levels that have threatened the fragile environment inside the burial chamber.

The restoration included an investigation of mysterious brown spots that were feared to be growing like a fungus in the wall paintings. Conservation workers confirmed that the spots were microbes, but they were long dead and had not in fact spread since Carter opened the tomb in 1922. What's more, the microbes had already grown into the paint layer, so they couldn't be removed from the wall paintings without damaging the artwork.



Extreme microbes have been discovered in the most hostile environment, like these high-temperature ocean vents

SCIENCE

Extreme microbes found inside ocean crystals

Words by **Mindy Weisberger**

Buried hundreds of feet under the ocean floor in the Sea of Japan, where bone-chilling temperatures and intense pressure discourage most forms of life, there live some very hardy microbes. Their deep-sea secret? They hunker down in pockets inside tiny mineral grains, which are then sealed into deep-sea crystals.

Scientists discovered the crystal-encased microbes during an expedition to Joetsu Basin to sample gas hydrates – crystalline solids of gas and water that form in the ocean under high pressure and intense cold. They presented their findings in December at the annual conference of the American Geophysical Union (AGU).

After the researchers examined massive hydrates collected from the seafloor off Japan's western coast, they found that some of the hydrates contained tiny grains of a mineral called dolomite. Dark spots in the dolomite hinted that there was yet another surprise to come, researcher Glen Snyder, a professor at Meiji University in Tokyo, Japan, told **Live Science** at the conference.

While the hydrates were quite large, measuring up to five metres long, the dolomite grains were tiny – about 30 microns, or 0.001 inches, in diameter, Snyder said. The researchers discovered the dolomite in residue left behind after they chemically separated the hydrates into gas and water.

Fluorescent staining of dark cores in the grains revealed that they contained genetic material, which glowed under UV light. It represented "high concentrations" of microbial matter, the scientists reported at the AGU meeting.

Microbes are known to live around gas hydrates. Nevertheless, it was entirely unexpected to find these nested microbial tenants inside mineral grains that were inside the hydrates.

Though this is the only known evidence of microorganisms encased in dolomite crystals, there may be other microbial opportunists elsewhere in the oceans, growing in saline chambers in gas hydrates.

In fact, temperature and pressure conditions on other planets such as Mars could also be just right for shaping gas hydrates, which could potentially serve as homes for Martian microbes, the researchers wrote.

The microbe-housing dolomites discovered in the Sea of Japan aren't very different from minerals found in Martian meteorites. This suggests that the Red Planet might present opportunities for microbial life to survive as it does inside dolomites on Earth.

The LHC took 30 years to build and is buried 100 metres underground

TECH

CERN to build biggest atom smasher ever

Words by **Yasemin Saplakoglu**

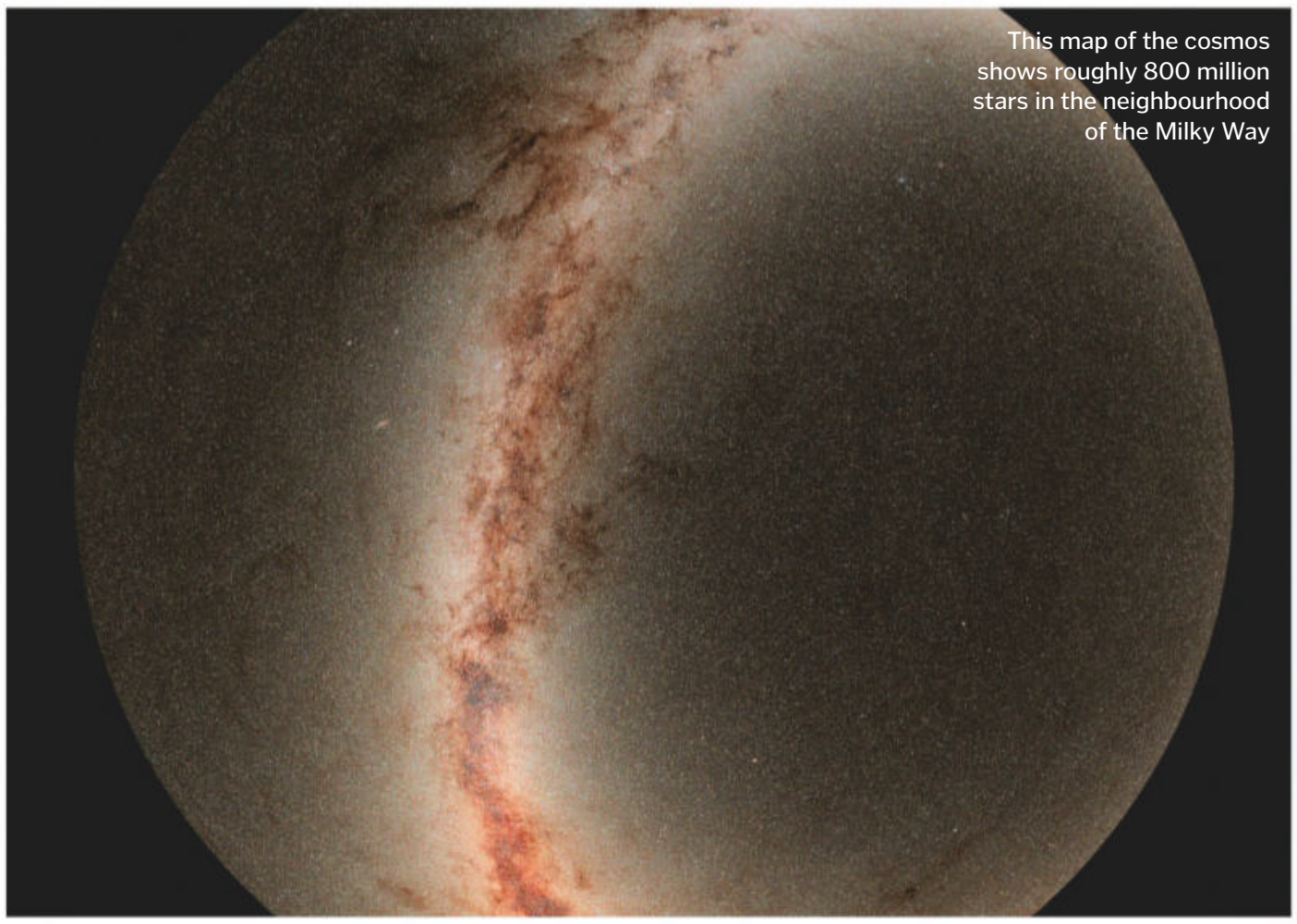
The European Organisation for Nuclear Research (CERN) plans to develop one of the most powerful particle accelerators to date. Known as the Future Circular Collider, it will have a circumference of 100 kilometres – nearly four times the size of the current record holder, the 27- kilometre ring called the Large Hadron Collider (LHC).The universe is filled with particles that we don't know about that are governed by rules we don't yet understand. However, by smashing familiar particles together at nearly the speed of light using these huge machines, physicists can sometimes glimpse the invisible.

IN ASSOCIATION WITH LIVESCIENCE

SPACE

Making an 800 million-star map of the sky

Words by **Brandon Specktor**



This map of the cosmos shows roughly 800 million stars in the neighbourhood of the Milky Way

At first glance, this looks like an image of a planet: dark, snow-speckled and slashed down the centre by a deep red scar. But zoom in a little closer and you soon realise you're in fact looking at something much larger than a planet – larger even than 100 billion planets. This is nothing less than a new map of the cosmos.

Compiled from four years of observations by the Pan-STARRS observatory in Maui, Hawaii, hidden within this mosaic of the Milky Way (that's the big red smear in the middle) and its cosmic neighbourhood are more than 800 million stars, galaxies and interstellar objects.

A chunk of the Milky Way galaxy slices through the middle of this image, growing brighter near the bottom of the frame where the galaxy's black hole-powered centre smoulders in the darkness of space. Clouds of interstellar dust, which absorb blue light and appear to glow red, puddle along the galaxy's length.

Soon, eager stargazers around the world will get an opportunity to study each of these objects (and many millions of others) in greater detail, and it's all thanks to what scientists working at the University of Hawaii at Mānoa (UH) have excitingly described as the biggest release of astronomical data in history. Who knows what galactic secrets may soon be discovered?

HISTORY

Opal-filled fossils reveal dog-like dinosaur

Words by **Laura Geggel**

When Mike Poben, an opal buyer and fossil fanatic, bought a bucket of opal from an Australian mine, he was surprised to find what looked like an ancient tooth in the pile. Later, he also found a fossilised jaw piece – one that was shiny and glistening with opal.

After showing the two opalised specimens to palaeontologists in 2014, Poben learned that they were part of a previously unknown dog-size dinosaur species. This dinosaur lived approximately 100 million years ago in Australia, back when the landscape was lush and dotted with lakes. The fossils originally came from a mine in Wee Warra, near the town of Lightning Ridge in New South Wales. The scientists accordingly gave the newfound Cretaceous-age dinosaur a fitting name: *Weewarrasaurus pobeni*.

"Weewarrasaurus was a gentle herbivore about the size of a kelpie dog [a type of Australian herding dog]," explained study lead researcher Phil Bell, a senior lecturer of palaeontology at the University of New England in Australia. "They got around on two legs and had a long tail used for balance. Because they were small and didn't have horns or particularly sharp claws for defence, they were probably quite timid and would have travelled in small herds or family units for protection."

In that sense these dinosaurs were likely the kangaroos of Cretaceous Australia, Bell told Live Science. "I think I would have liked one as a pet."

This dinosaur belonged to the Ornithopods, a genus of grazing herbivores

HEALTH

Drug changes cancer into fat

Words by **Rachael Rettner**

Imagine if you could turn aggressive cancer cells into harmless fat. Scientists in Switzerland say they've done just that in a new study on mice. By taking advantage of the 'plasticity', or adaptability, of certain cancer cells during metastasis, the researchers were able to coax breast cancer cells in mice into becoming fat cells.

The scientists accomplished this using a combination of two drugs, both of which are already approved for use in humans by the US Food and Drug Administration (FDA). The treatment didn't convert all of the cancer cells into fat cells, but it did stop the cancer's spread to other parts of the body.

The work is very preliminary, and it's unclear if the findings will apply to people or to other types of cancers. Even so, because the study used two drugs already approved by the FDA, it "may be possible" that the findings also apply to humans, the researchers wrote in their paper, which was published in the journal *Cancer Cell*.

Turning cancer cells into normal fat cells would stop the changes occurring that allow the disease to spread through the body

IN ASSOCIATION WITH LIVESCIENCE

HEALTH

Maggots used to heal the injured

Words by **Laura Geggel**

Maggots can be creepy, crawly and… medicinal? In a new effort to heal wounded people in war zones, the UK Government is sending maggots to places like Syria, Yemen and South Sudan, according to *The Telegraph*. Once these larvae, often those of green bottle blowflies, are connected with patients they get right to work, keeping wounds free of contamination by feeding on dead human tissue and spreading their antibacterial saliva.

This macabre treatment may sound unusual, but it's actually a remedy that dates back to ancient times. For instance, the Australian Aboriginal peoples used maggots to clean wounds, and during World War I soldiers in trenches also used the critters to keep injuries free of potentially deadly infections. Now this therapy may help people with festering wounds stay free of infection. The £200,000 ($250,000) project may even help wounded people keep their limbs, as secondary infections from injuries and operations can lead to amputations.

"People living through conflict and humanitarian crisis are still dying from wounds that could so easily be healed with the right access to care," UK Secretary of State for International Development Penny Mordaunt, who is also an MP, told *The Telegraph*.

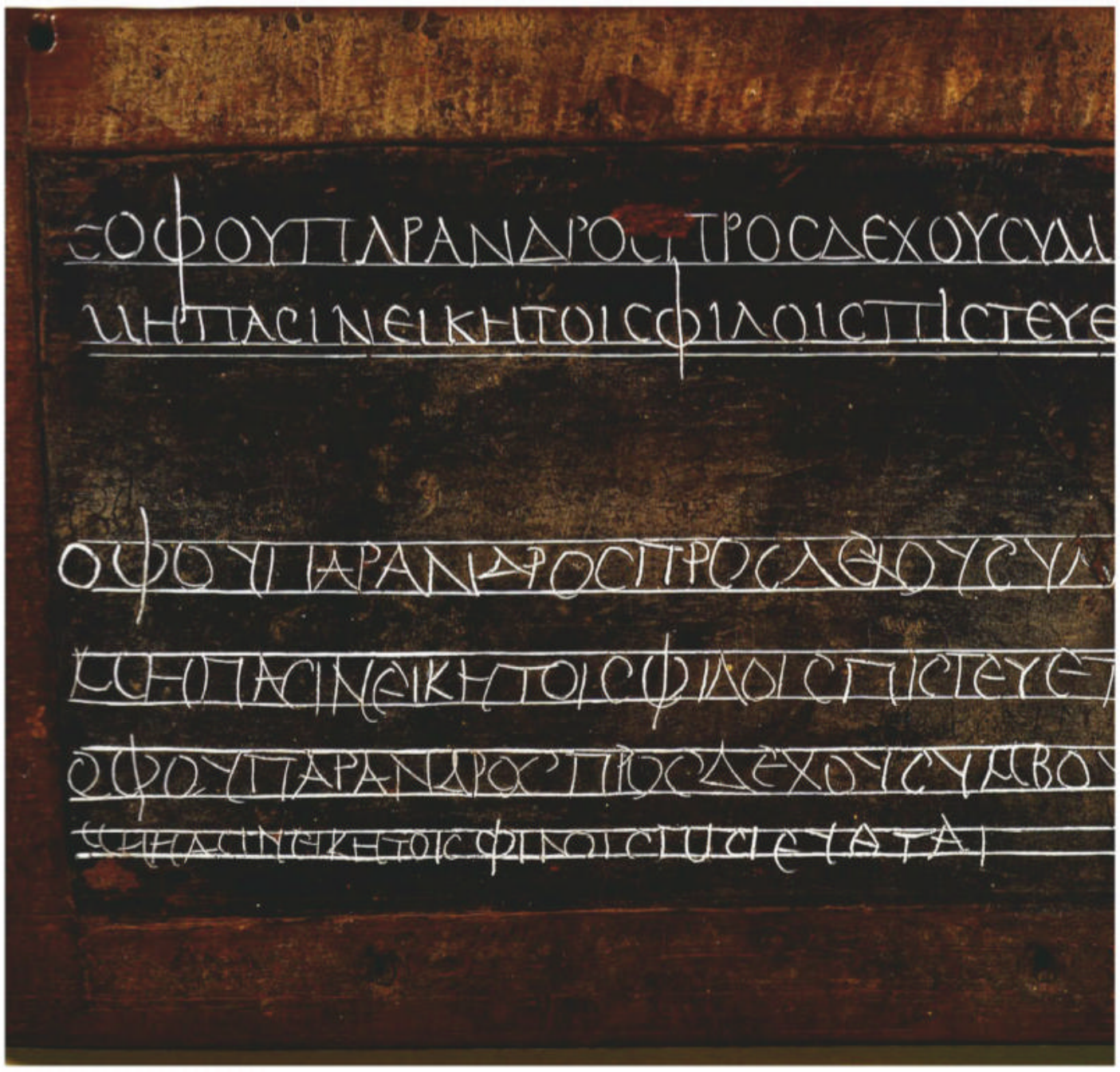
To roll out 'project maggot' the UK will have field hospitals raise maggots on location. Once the fly eggs are laid they will be sterilised and then incubated for a day or two. At this point the maggots will be ready for the prime time, when they can be put directly into wounds or placed in BioBags, which are then wrapped around injuries, *The Telegraph* reported.

> *"These baby bugs can digest dead and damaged tissue from an open wound"*

Sterile maggots are very valuable in places that have limited or basic medical treatment. These baby bugs can digest dead and damaged tissue from an open wound, according to a 2012 report in the *Indian Journal of Plastic Surgery*. Maggots can even cleanse wounds faster than surgeons, as reported by **Live Science**.

However, to prevent the spread of disease these maggots can't be used twice, so researchers have directed that the larvae be disposed of in clinical containers after each use. If some escape into the wild it shouldn't be a problem, as maggots undergo a sterilisation process when they become flies.

Could maggots be the future of healing wounded soldiers?



A schoolchild's homework in Greek was written on a wax tablet nearly 2,000 years ago

HISTORY

Ancient Egyptians had homework

Words by **Mindy Weisberger**

Homework written by a schoolchild in ancient Egypt has been preserved since the second century CE. The words on the slab may sound familiar to any child whose parents worry about them falling in with the wrong crowd. An ancient text preserved on a wood-mounted wax slab around the size of a Kindle device warns pupils that "You should accept advice from a wise man only" and "You cannot trust all your friends."

Acquired by the British Library in 1892, the tablet hasn't been publicly displayed since the 1970s. The homework slab will be featured in an upcoming British Library exhibit called *Writing: Making Your Mark*, which traces the evolution of writing over 5,000 years of human history, library representatives said in a statement.

On the wax tablet is a two-part lesson in Greek that provides a snapshot of daily life for a pupil attending primary school in Egypt about 1,800 years ago, exhibit co-curator Peter Toth, also a curator of ancient and medieval manuscripts at the British Library, told **Live Science**.

One part of the assignment was a writing exercise. The slab displays a teacher's neatly written example in the first line, and the next two lines contain the same words copied "rather clumsily" in the student's hand, much as primary students today copy lines penned by their teachers (usually as a form of punishment), Toth said. The rest of the homework included a multiplication table and reading exercises.

"The ancient text warns pupils that 'You cannot always trust your friends'"

SPACE

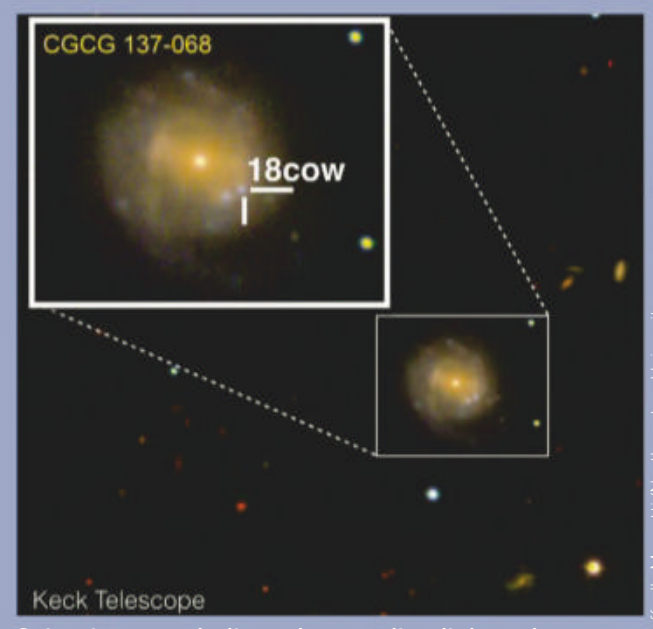
Astronomers observe first black hole explosion

Words by **Brandon Specktor**

On 16 June 2018 a stupendously bright explosion tore across the cosmos and lingered in the sky above Earth for several weeks. The mysterious blast travelled 200 million lightyears from the gut of the Hercules constellation, shone with the light of nearly 100 supernovae and captured the attention of the world's stargazers until, finally, it vanished from the sky as mysteriously at it appeared. Astronomers named it The Cow.

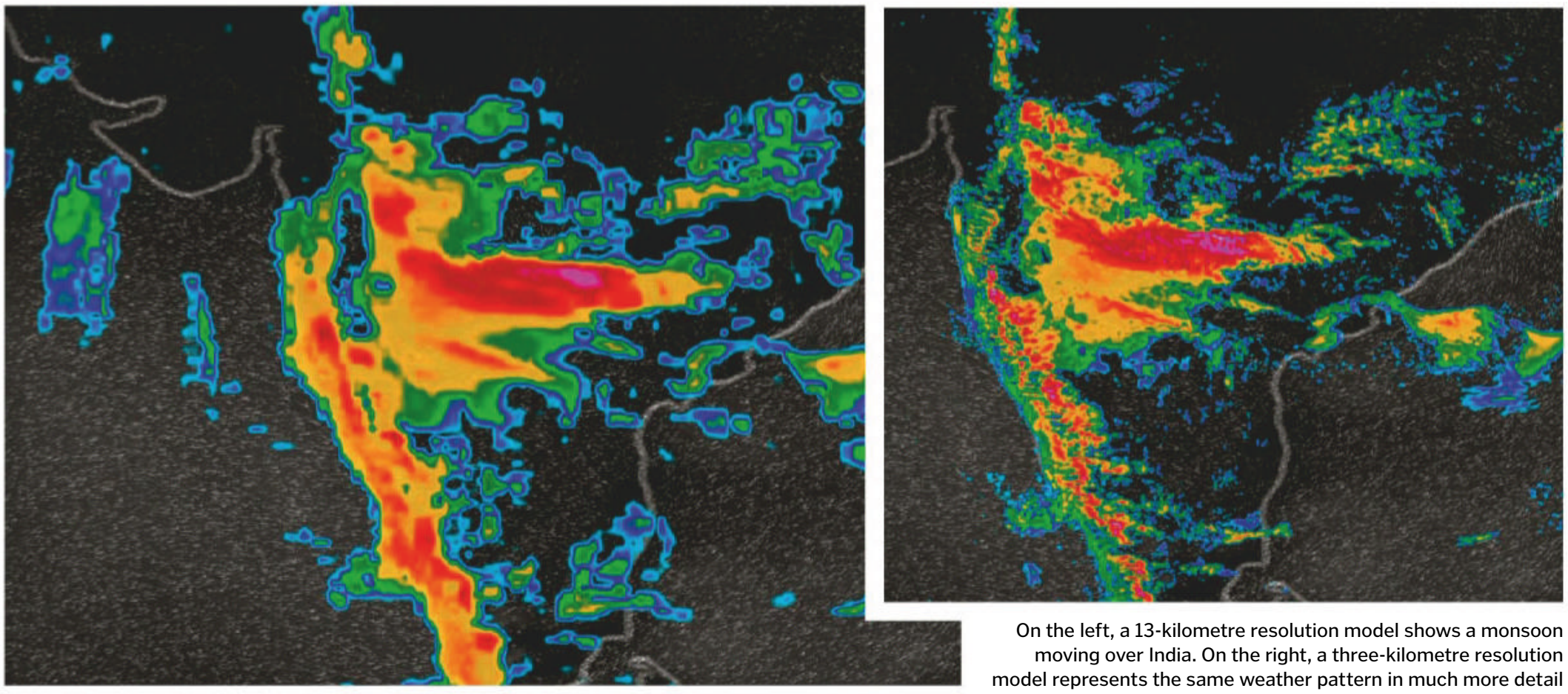
From the moment of its discovery, scientists knew that The Cow (officially named AT2018cow, which is a procedurally generated name) was no typical supernova. Now, months later, a team of international researchers is prepared to argue that The Cow is actually an incredible astronomical first: the birth of either a black hole or neutron star, witnessed live from Earth for the first time in recorded history.

"We know from theory that black holes and neutron stars form when a star dies, but we've never seen them right after they are born. Never," Raffaella Margutti, an astrophysicist at Northwestern University in Evanston, Illinois, US, and lead author of a forthcoming paper on The Cow, said in a statement.



Scientists now believe the startling light to have been the exact moment a black hole or neutron star was born

IN ASSOCIATION WITH
LIVESCIENCE



On the left, a 13-kilometre resolution model shows a monsoon moving over India. On the right, a three-kilometre resolution model represents the same weather pattern in much more detail

PLANET EARTH

Super-accurate weather forecasts incoming

Words by **Rafi Letzter**

Global weather forecasts are getting a big technology upgrade. Right now, people in the United States, Japan and parts of Europe have access to hourly forecasts based on a wealth of data and high-resolution computer models. That usually means that if a storm is going to hit, there's enough radar and computing power trained on the atmosphere over the US for Americans to be able to find out when and where far in advance just by checking their phones. Much of the wealthy world lives in a sort of protective bubble of weather forecasting, warning of incoming storms and other dangers. But The Weather Company claims it's about to change that.

The Weather Company, a subsidiary of IBM that operates The Weather Channel as well as Weather Underground, recently announced a project it calls the IBM Global High-Resolution Atmospheric Forecasting System (GRAF). GRAF, the company claims, "will be the first hourly updating commercial weather system that is able to predict something as small as thunderstorms globally".

The major advance of GRAF isn't that it detects new data but that it processes more data in a more detailed way and more quickly than had previously been possible on a global scale. How well it works will ultimately depend on the quality of the data fed into it. The Weather Company said in an email that global GRAF forecasts would be available to anyone with a Weather Company app later in 2019.

ANIMALS

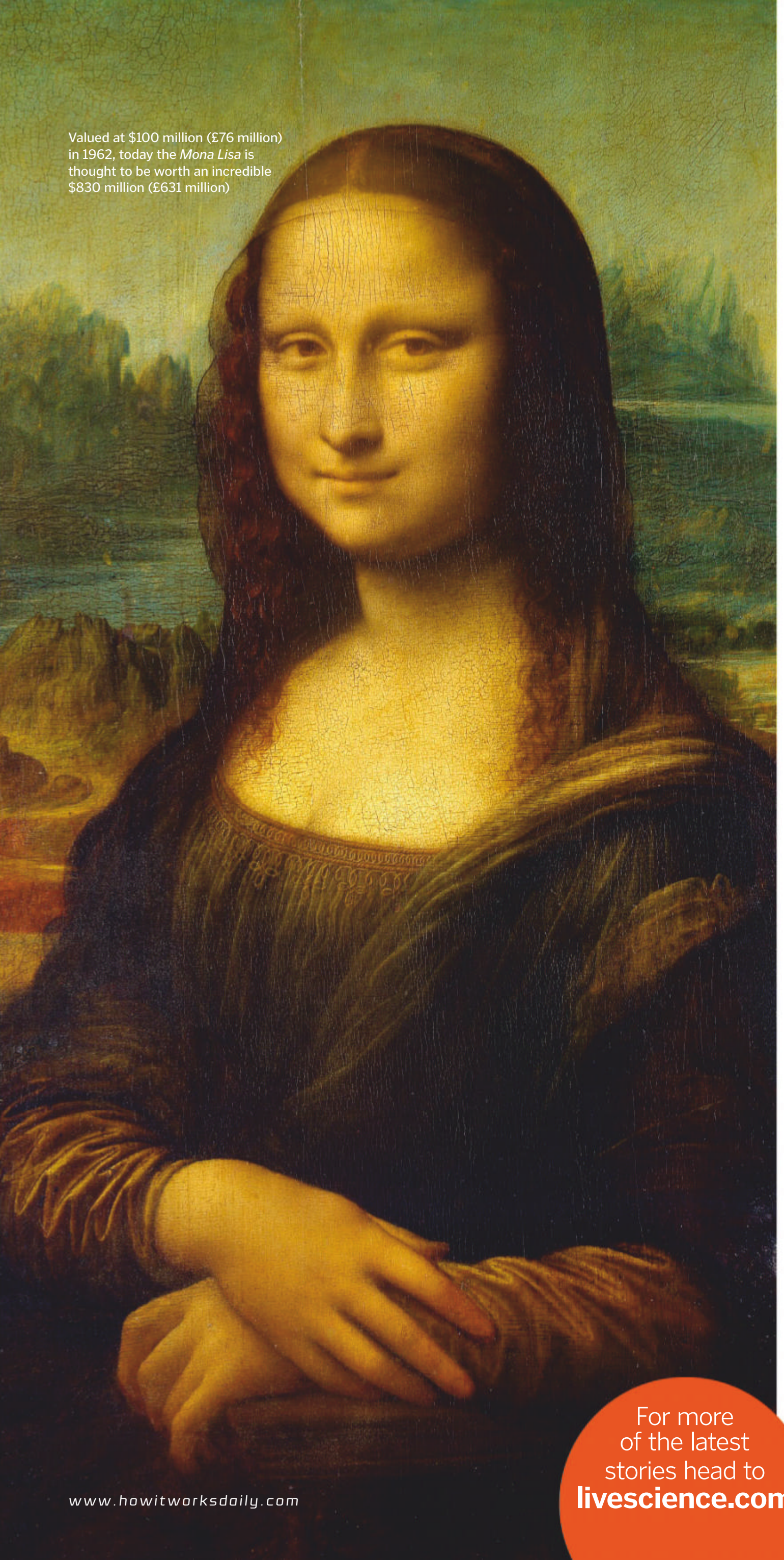
Galápagos finch's bite stronger than a T-rex's

Words by **Mindy Weisberger**

The mighty T-rex's bite was far less impressive for its body size than the bite of a much smaller modern dinosaur, the tiny Galápagos finch. Researchers recently crunched the numbers to evaluate the crushing strength of the bites of hundreds of animals, living and extinct. They used supercomputers to evaluate bite force and body mass and track evolutionary changes in jaw power in animal groups that included mammals, reptiles and birds.

When the calculations were done the scientists found that the Galápagos finch, which like all birds are living dinosaurs, packs a bite that is unexpectedly powerful. In fact, if this species of finch were scaled up to T-rex size its bite would be 320-times stronger than that of its extinct cousin!

Bite strength in Galápagos finches is unusually powerful for their size



Valued at $100 million (£76 million) in 1962, today the *Mona Lisa* is thought to be worth an incredible $830 million (£631 million)

STRANGE NEWS

Mona Lisa 'gaze' a myth

Words by **Stephanie Pappas**

It's common knowledge that the woman in Leonardo da Vinci's most famous painting seems to look back at observers, following them with her eyes no matter where they stand in the room. But this common knowledge, it turns out, is wrong. The eyes of the woman in the *Mona Lisa* don't follow viewers at all. A new study has found that the woman in the famed painting is actually looking out at an angle that's 15.4 degrees off to the observer's right. In other words, said study author Gernot Horstmann, a perceptual psychologist at Bielefeld University in Germany, "She's not looking at you." This is somewhat ironic, because the entire phenomenon of a person's gaze in a photograph or painting seeming to follow the viewer is called the 'Mona Lisa effect'.

Horstmann and his co-author, computer scientist Sebastian Loth, were studying this effect for its applications in the creation of artificial-intelligence avatars when Horstmann took a long look at the *Mona Lisa* and realised something. "I thought, 'Wait, she's not looking at me.'"

To make sure it wasn't just him, the researchers asked 24 people to view images of the *Mona Lisa* on a computer screen. They set a ruler between the viewer and the screen and asked the participants to note which number on the ruler intersected Mona Lisa's gaze. To test whether the painting's other features made any difference in the way her gaze was perceived by the observer, the researchers altered the zoom on the image, changing whether the woman's eyes and nose or entire head were visible. To calculate the angle of Mona Lisa's gaze as she looked at the viewer, they moved the ruler further from or closer to the screen partway through the study. This provided them with two points to work with, making it possible to calculate the angle.

Consistently, the researchers found, participants judged that the woman in the *Mona Lisa* portrait was not looking straight at them but slightly off to their right. So why do people repeat the belief that her eyes seem to follow the viewer? Horstmann isn't sure. It's possible, he said, that people have the desire to be looked at, so they think the woman is looking straight at them, even when she's not. Or maybe, he said, the people who first coined the term 'Mona Lisa effect' just thought it was a cool name.

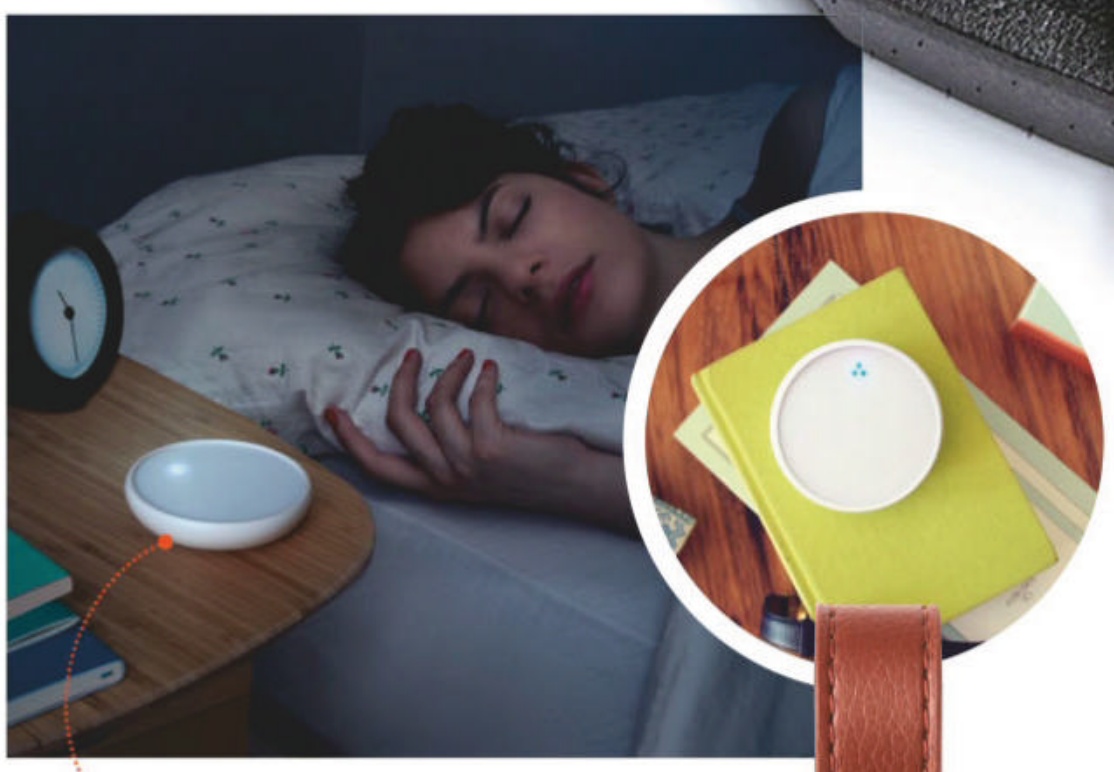
WISH LIST

The latest must-have technology

Airblock

■ Price: **approx. £140 / $179.99**
www.makeblock.com

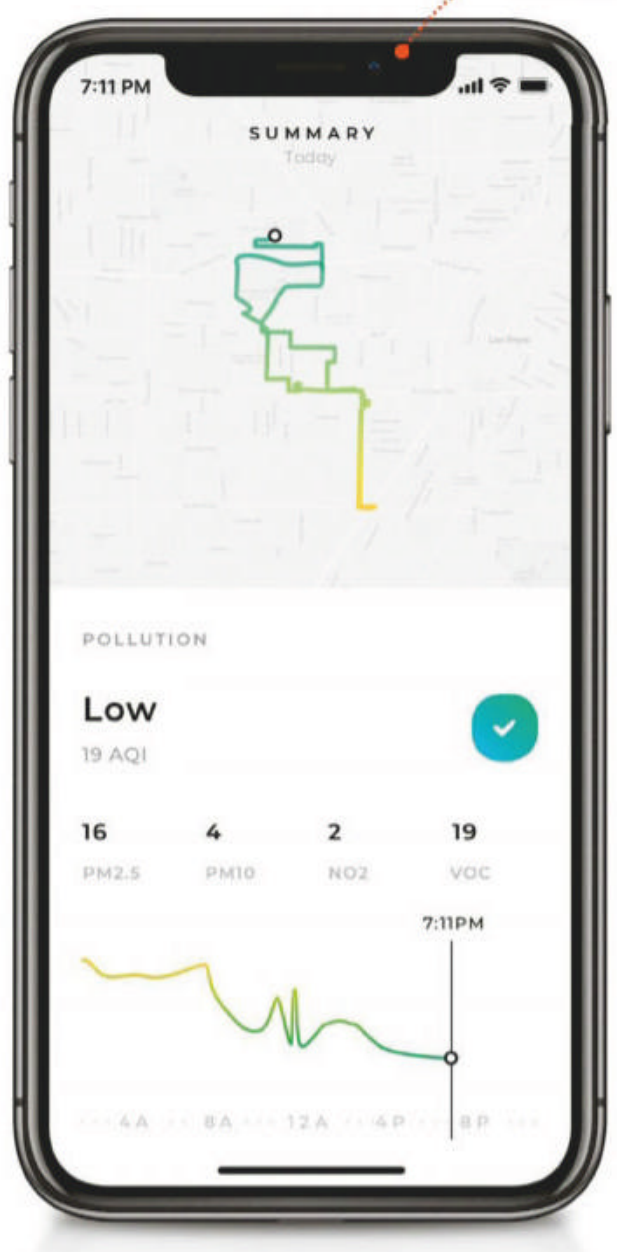
Though the drone revolution is well underway, the Airblock is much more than a typical drone. With the use of its detachable hexagonal power modules the Airblock can become so much more. By changing the modules' configuration, the Airblock can become a hovercraft or whatever your imagination can create. With the accompanying software, users can learn and experiment with programming to control flight and movement, making Airblock a great teaching tool.



Dodow

■ Price: **£49 / $59** **www.mydodow.com**

When was the last time you felt really relaxed? For many of us, finding five minutes of calm in our busy days can be difficult and falling to sleep even harder. But this new 'light metronome' by Dodow is a game-changer. Just before you go to sleep, usually when the anxieties of the day start to rattle around your brain, just one tap on this sleep aid projects a blue circle of light onto your ceiling. The halo expands to signal to the user to inhale and shrinks while they exhale. By encouraging deep, slow breathing, the Dodow works to calm people and encourage them into a deeper sleep. In fact, it has been shown to help people fall to sleep 2.5-times faster on average.



Flow

■ Price: **£159 / $179**
www.plumelabs.com

Pollution in our cities has been a rising concern, especially to those who often stroll through them. Flow, created by Plume Labs, is a compact detection device that puts pollution on the map – literally. Through a series of holes on the Flow's exterior, the incoming air is analysed by internal sensors. Paired with its mapping app, Flow records the air quality during your journey, creating a comprehensive map of your route and indicating areas of high and low pollution.

The Amazon Smart Plug

Price: **£24.99 / $24.99** www.amazon.co.uk

You know that feeling when you finally get settled down to watch a film and you remember you left a light on in the hallway? Well, thanks to the new Amazon Smart Plug you no longer have to get up from the sofa to switch it off. By adding voice control to any socket and working with Alexa these smart plugs can give you control over everything from a coffee machine to your bedside lamp.

iRobot Braava Jet 240 Robot Mop

Price: **£249.99 / $199.99** www.irobot.co.uk

Powerful, automated, and small enough to get into even the toughest-to-reach areas of your home – this robot mop is everything we have waited for. Perfect for tiles, stones and other hard floor surfaces, the iRobot Braava Jet 240 features precision jets and a vibrating head to clean even the grubbiest surfaces. The built-in Cliff Detect function stops your cleaning buddy launching itself down the stairs, and it will navigate around your furniture too. Just fill it up with water and detergent and let it loose.

QuietOn

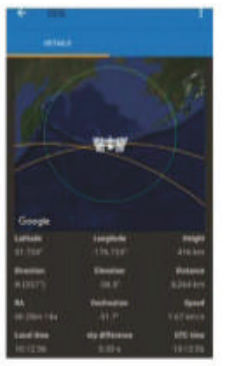
Price: **approx. £155 / $199** www.quieton.com

The world is filled with an array of noise, potentially hindering our focus at work. QuietOn has been developed to cancel out sound and remove distractions caused by noise. These wireless earbuds use a tiny microphone that, when placed inside the ear canal, delivers phase-shifted sound to cancel out the buzz of the office printer or the bustling sounds of commuters. By making a cacophony of aircraft engines or the rattle of a train seem like a gentle hum, QuietOn can aid with sleep on transport too.

APPS & GAMES

ISS Detector Satellite Tracker

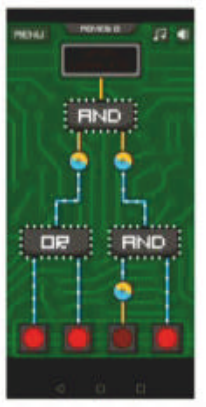
- Developer: **RunaR**
- Price: **Free / Google Play / App Store**



This tracker app allows you to follow the path of the International Space Station and Chinese space station, Tiangong-2. Using an inbuilt radar, it can give you a chance to catch a glimpse of the ISS high up in the night sky.

Circuit Scramble – Computer Logic Puzzles

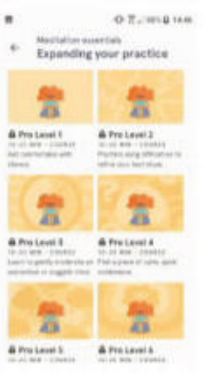
- Developer: **Suborbital Games**
- Price: **Free / Google Play**



Dive into computer circuits with this fun puzzle game. Follow the flow of current to complete each level while navigating several input obstacles. The app also features 135 custom-made levels and Endless Mode.

Headspace: Meditation & Mindfulness

- Developer: **Headspace Inc**
- Price: **Free / App Store / Play Store**



Did you know that meditation has been scientifically proven to reduce stress and anxiety? If you could do with finding a little oasis of peace in a hectic lifestyle we can highly recommend this excellent app.

Screen Time

- Developer: **Simple App Ltd**
- Price: **Free / Play Store**

Spending too much time in front of our computers and other devices is a growing problem. You can use this handy app whenever you think you've been scrolling on Facebook or gazing at your phone for too long.

DID YOU KNOW? *The first asteroid ever discovered was Ceres in 1801, a huge object later reclassified as a dwarf planet*

IMPACT EARTH!

How massive meteorites have shaped our planet for better and for worse

Words by **Jonathan O'Callaghan**

Earth sure hasn't had it easy. Throughout its life our planet has been repeatedly hit, pummelled and even shattered by incoming space rocks, at times wiping out vast swathes of life and significantly changing our planet's habitability. But these mega impacts haven't just caused mass extinctions; they've also been responsible for allowing life to thrive here in the first place, and our very own Moon may owe its existence to a colossal impact long ago.

Our Solar System is full of asteroids and comets, pieces of debris left over from the Sun's infancy that failed to form into planets. Some of these orbit close to Earth and are known as near-Earth asteroids, the ones that make the closest passes to our world. The majority of asteroids in our Solar System can be found in the asteroid belt between Mars and Jupiter, home to millions of asteroids, with the largest being Vesta, which has a mean diameter of 530 kilometres. Farther out in the Solar System you'll find Trojan asteroids, which share orbits with the larger planets, and in the outer Solar System, the Kuiper Belt and beyond you'll find pieces of icy rock. Occasionally, a comet from out here makes its way towards Earth.

If one of these rocks gets set on a collision course with Earth the consequences for us can be dire. Most debris from the Solar System simply burns up in our atmosphere and causes us few problems, becoming what's called a meteor. If they're big enough, however, they can make it to the surface in the form of a meteorite. And the bigger a meteorite is, the bigger an impact it'll have on our planet. We measure the impact an asteroid could have on

"OUR PLANET HAS BEEN REPEATEDLY HIT BY SPACE ROCKS"

Professor Kurt Kjær collecting a sample from the newly discovered Hiawatha Crater in Greenland

our planet using the Torino Scale, which ranges from 0 to 10. An object at the lower end has less chance of an impact and poses few dangers to life on Earth. At the upper end an impact is a near certainty, and the prospects for life surviving are slim. Fortunately, we know of no objects above a zero on the scale at the moment.

In the past, of course, we have indeed been hit by such objects, although long before modern humans were around. Most of these impacts leave noticeable scars on our surface in the form of craters. For impacts that happened long ago, these craters can be hidden beneath new land, requiring us to dig underground or search underwater for remnants of them. For the most part, with our detailed satellite imagery of the planet, we've done a pretty good job of finding most of the noticeable craters.

> "HOW DID ONE SO BIG MANAGE TO AVOID OUR DETECTION?"

In November 2018, scientists announced the discovery of a huge new crater hiding beneath the Greenland ice sheet. Called the Hiawatha Crater, this mammoth depression measures 31 kilometres across, making it one of the 25 largest impact craters on Earth. This is not only the biggest new crater discovered in recent history but the first crater we have ever found under an ice sheet. Its existence suggests there could be many more discoveries to come.

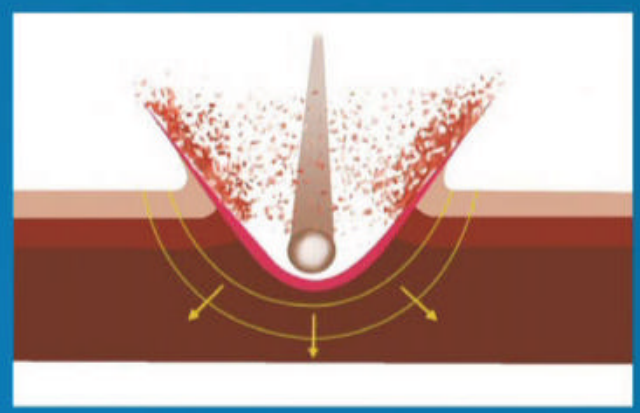
This crater was found by flying over Greenland and using ice-penetrating radar to peer below the ice. Scientists use this technique to monitor the effects of climate change and see how much ice is melting. They were surprised to discover something else too. As the ice continues to melt and the landscape changes it is revealing previously undiscovered features – including a huge impact crater. Once the team had spotted what looked like a hidden crater they began to optimise and enhance the available data to see if they could get a better picture of it. This included taking further radar images in May 2016 in an attempt to create a clearer picture of what was under the ice. These results showed their initial assumption had been correct – there was a larger crater with a rim around it.

To find out what might have caused the crater, Professor Kurt Kjær from the Natural History Museum of Denmark – who led the project – travelled to the site in July 2016 to collect samples. The crater is buried several kilometres below the ice, so it is not possible to directly sample it, but Professor Kjær found that part of the glacier that housed the crater was melting, meaning meltwater containing minerals from the crater was seeping out. He collected samples of this water and found the smoking gun that pointed to an asteroid impact. The meltwater contained quartz grains that had been shocked, most likely by an impact.

It is thought that this crater was caused by an iron asteroid measuring about 1.5 kilometres across striking the Earth's surface at a velocity of 20 kilometres per second. This would give it an impact force large enough to have caused this

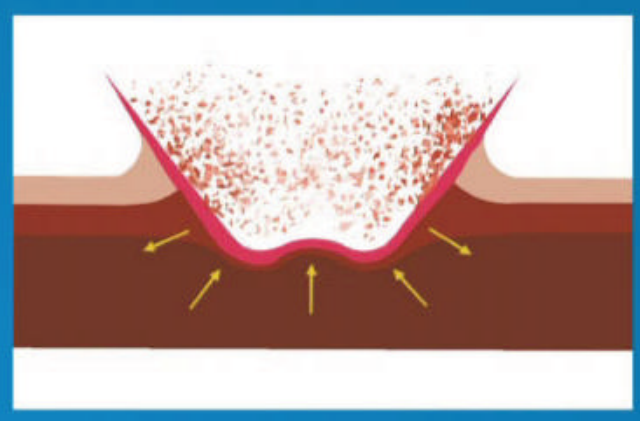
Making a big impression

How the classic crater formation is created by large impacts



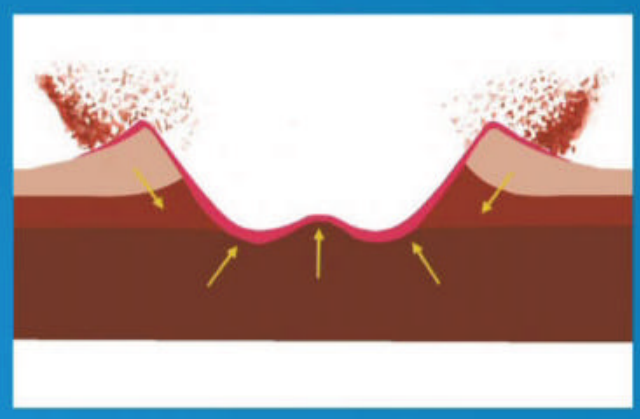
Smashing the surface

Complex craters are formed by large impacts, tending to be wider across but shallower in depth (compared to their diameter) than simple craters formed by smaller impacts.



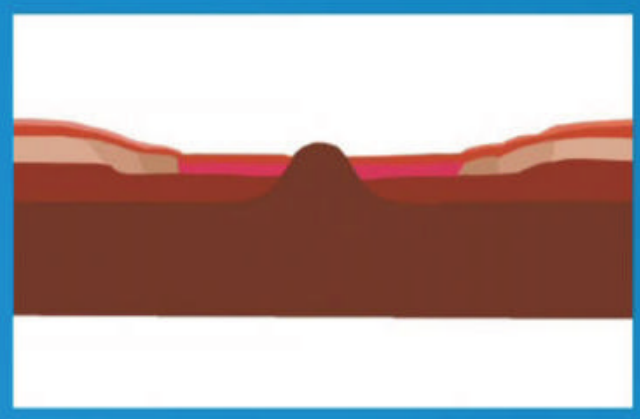
Crater walls

The force of the impact causes the walls to collapse downwards, adding debris to the interior of the crater and decreasing its depth.



Central peak

Complex craters also have a hump in the middle, where material has rebounded from the impact to form a shallower mound that protrudes upwards.



Final diameter

On Earth, complex craters tend to be more than four kilometres in diameter. On different planets, gravity has a significant effect on the type of crater formed.

www.howitworksdaily.com

The Hiawatha Crater is believed to have been caused by a huge rock rich in iron

Impact events may have caused multiple extinction events on Earth

huge crater beneath the ice sheet. The next largest impact crater is the Tookoonooka crater in Australia, which measures 66 kilometres across. But both pale in comparison to the biggest impact crater found on Earth to date, the Vredefort Crater in South Africa, which has a whopping 300-kilometre diameter.

Most of these larger craters were discovered long ago, so how did one so big manage to avoid our detection for so long? The answer mostly lies in our ability to map below the surface. While we have satellite imagery of pretty much the whole planet, peering beneath the surface is a bit more difficult. But with more and more radar-equipped planes flying over the ice sheets, we're now able to more easily look below this ice to monitor climate change. In so doing we're also able to make fascinating discoveries like this. There may well be more such discoveries awaiting us under the ice.

The Hiawatha Crater is not a closed case just yet though. One of the biggest unanswered questions about this impact is when it took place. The team currently think it occurred anywhere from between 12,000 to 3 million years ago, making it our most recent impact by far – the last major meteorite event before this occurred about 40 million years ago. We know that large impacts like these can have a profound effect on life on our planet, so is it possible the Hiawatha Crater heralds an extinction event?

Scientists have previously struggled to explain the sudden mass extinction of many species that began about 12,900 years ago, called the Younger Dryas. This led to the death of many large animals known as megafauna, while an early human society known as the Clovis people disappeared completely from the archaeological record. Some have suggested a cooling effect on the planet took place, but the reasons aren't

Meteors burn up in our atmosphere, whereas meteorites reach the surface

Asteroids, meteors, meteorites and comets

An asteroid is a piece of rocky debris left over from the formation of our Solar System that continues to orbit the Sun. Comets are similar, but they formed farther out in the Solar System and are thus likely to have considerably more ice than asteroids, as well as distinctive 'tails' of material. A meteor is an asteroid that enters our atmosphere but burns up, sometimes appearing as a shooting star. They are typically quite small and do not reach the surface. A meteorite is an asteroid or comet that does reach the surface and can be anything from a small rock to a huge crater-forming leviathan.

Q&A

Professor Kurt Kjær, Natural History Museum of Denmark

The lead author of the paper published in *Science Advances* talks about the discovery of the Hiawatha Crater

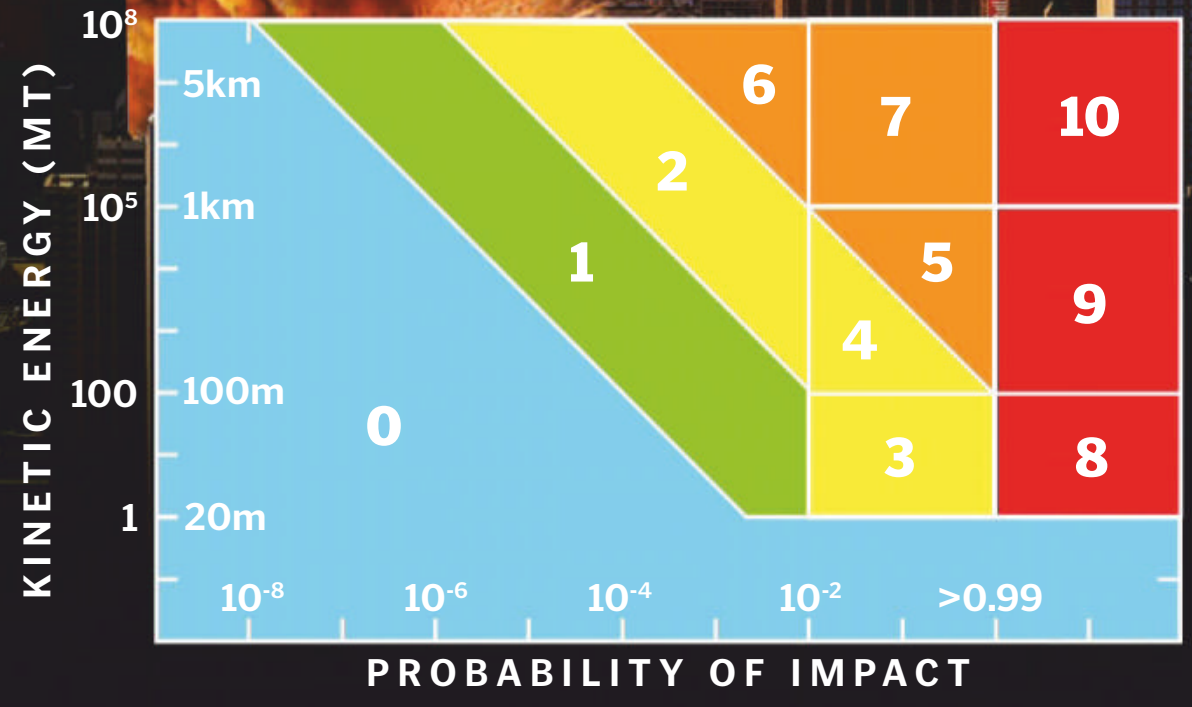
Why was this discovery so exciting?
How often do you find a new, well-preserved impact crater on Earth that is so obvious when you see it? I think it's super exciting because we have thousands of satellites orbiting Earth, we have planes flying everywhere, we record everything that happens on Earth's surface. To discover a thing like this, despite all of these things, in this age where we can see everything from a satellite, it really is a true discovery. You don't have the opportunity as scientists to do that very often.

Why had we not seen this crater before?
Our knowledge of the topography beneath the Greenland ice sheet is getting better and better all the time. Operation IceBridge from NASA has done a great job of doing this, because they map the ice sheets themselves and also map the base of the ice sheets with ice-penetrating radar. A new hidden landscape has started to emerge.

Do we have an idea of when it happened?
When it came out, a lot of people threw themselves on the Younger Dryas hypothesis. We do not do that in the paper. We say we cannot confirm if that is the case, but we cannot reject that hypothesis either. So it might be young – 11,700 years old – very young. And there's some indication [that's the case] due to how it's shaped, how well preserved it is.

The Torino Scale

The Torino Scale is a way for us to rank how dangerous a potential impact with Earth could be. The scale ranges from 0 to 10 and is used by scientists to inform the public about the impending danger of an asteroid. The lowest ratings refer to objects that are either unlikely to hit us or are so small that they will simply burn up in our atmosphere. Those in the mid ranges refer to objects that are expected to come close to our planet so have a chance of hitting and are big enough that they could cause a considerable amount of damage. The upper end of the scale is reserved for objects that are certain to hit us and are so large that they could threaten life on our planet. Fortunately, at the moment we know of no objects that are above a 0 on the scale.



BLUE
There is essentially zero chance of a collision, or the object is too small to cause us any danger.

GREEN
The chance of a collision is very unlikely, so there is little cause for concern.

YELLOW
There is a one per cent or greater chance of an impact, which could cause localised destruction.

ORANGE
A very close encounter is predicted within decades, and governments may need to prepare for an impact.

RED
A collision with our planet is a certainty, and the object could threaten our civilisation on Earth.

completely clear. A possible explanation is that a large impact caused the planet to cool – the Hiawatha Crater may be evidence of this.

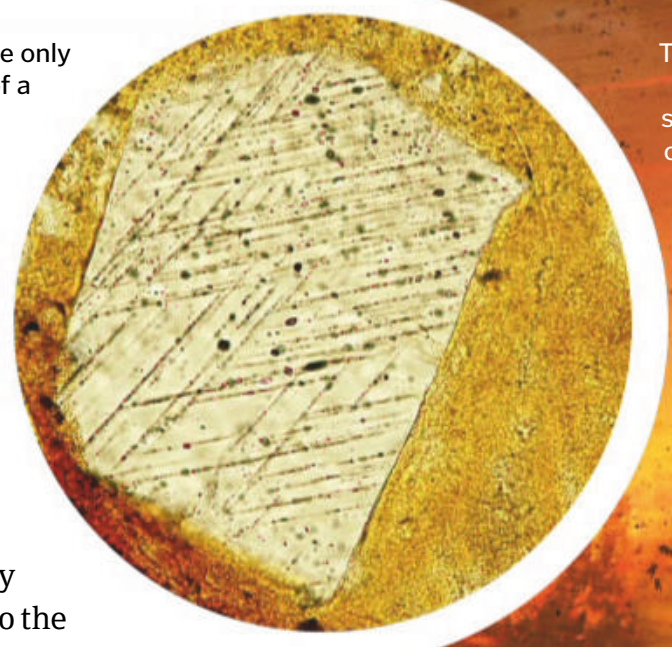
Looking far back into Earth's history we know that other meteorites have played a major part in our planet's evolution. Right back to the birth of our planet, 4.54 billion years ago, we think that meteorites were repeatedly slamming into the surface. Asteroids and comets are both rich in water, so a popular hypothesis is that these rocks were responsible for actually bringing the initial water to the Earth. We have also discovered that some space rocks are also rich in the ingredients of life, known as 'organics'. So life on Earth might have originated in a monumental impact long ago.

Then there's the Moon. Studying samples returned by the Apollo missions in the 1960s and 1970s, scientists were surprised to learn that Earth and its satellite shared similar chemical signatures. This led scientists to consider that the Moon may actually be a piece of Earth itself. This is known as the giant-impact hypothesis.

"WE SEE CRATERS ALL OVER THE PLACE"

The idea is that a large object dubbed Theia, possibly the size of Mars, slammed into our planet about 4.5 billion years ago. This colossal impact ejected a huge amount of debris into Earth orbit that, over time, gradually coalesced into the Moon. Some questions remain, however, including how our planet would have actually survived such an impact. But at the moment this is the best theory we have to explain how the Moon formed, and it all started with a massive bang.

We are pretty sure that throughout Earth's history other, smaller impacts also had major effects on life. One of the most famous such events was the Chicxulub impact about 66 million years ago. A huge crater 180 kilometres wide in the Gulf of Mexico, it points to a large impact from an asteroid or comet up to 15 kilometres across, with a faint trace of this crater remaining today. A drilling project took place to try and directly sample this crater after it had been discovered in the 1990s. This event is thought to have brought to an end the



These scars of shocked quartz are only created by a shock on the scale of a meteor impact

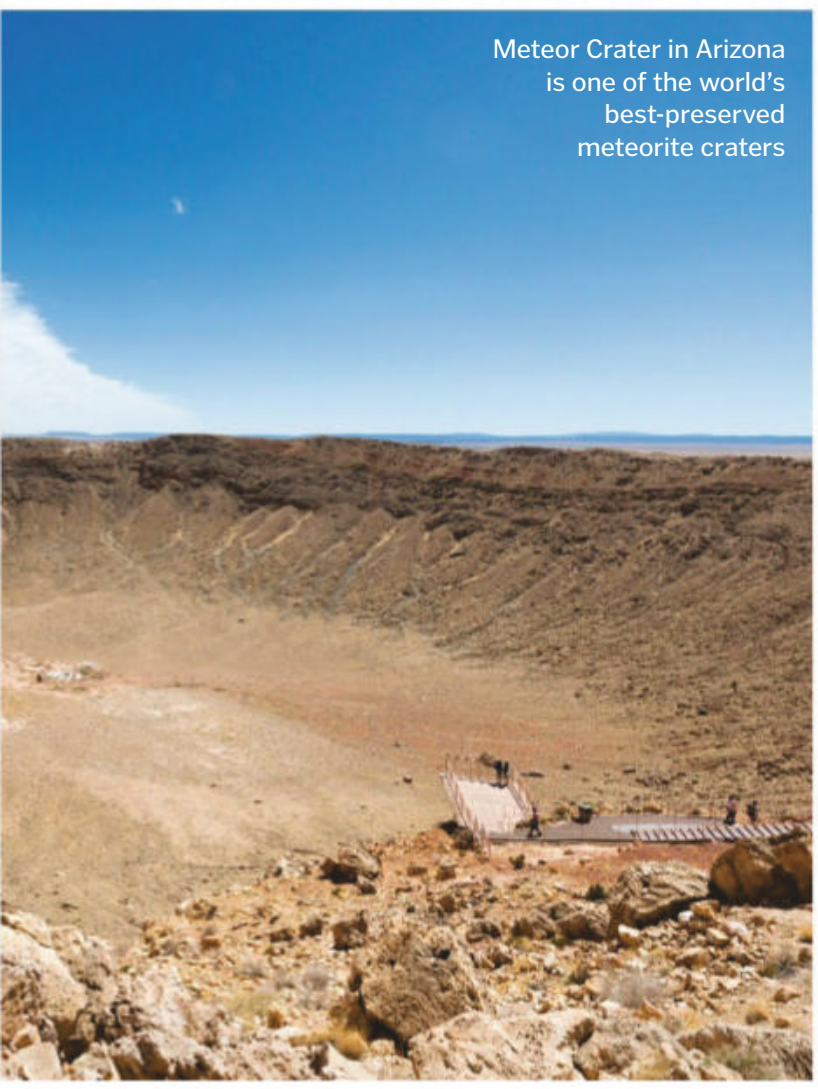
The dinosaurs (along with many other species) were wiped out by mega impact

Cretaceous period on Earth, with 75 per cent of life – including most of the dinosaurs – wiped out as a result of a chain of global catastrophes triggered by the impact.

Earth, of course, is not the only world in our Solar System that's been shaped by impacts. Our Moon is home to the South Pole-Aitken Basin, a vast crater roughly 2,500 kilometres in diameter. Another on Mars – called Utopia and measuring 3,300 kilometres across – is thought to be the largest of all. Throughout history each planet has been bombarded by objects, so Earth is no exception.

While the prospect of an asteroid hitting Earth might be terrifying – and there is plenty of evidence such events are catastrophic – we may very well owe our own beginnings to space rocks crashing into Earth. Thankfully, we know of no asteroid on a path with Earth that could result in another large impact event, but it's likely we will face such a prospect in future.

Studying the history of our planet and finding new craters like the Hiawatha Crater is vital to working out what effect these impacts have on our planet and what our prospects of surviving long into the future are. The very existence of life on Earth may one day rely on the scientists who examine the devastation of the past.



Meteor Crater in Arizona is one of the world's best-preserved meteorite craters

10%

of known near-Earth asteroids are PHAs (potentially hazardous objects)

IN 2010, HUBBLE SAW THE AFTERMATH OF TWO ASTEROIDS COLLIDING

ESA's Hera mission aims to reach a binary asteroid in the 2020s

2,000 years

Average passage of time before a football pitch-sized meteorite hits Earth

25 metres

Smallest size for an asteroid to pass through Earth's atmosphere

Asteroids in similar orbits typically came from the same parent

1km

Minimum meteorite size for disastrous worldwide effects

SOME ASTEROIDS ARE RICH IN USEFUL METALS LIKE PLATINUM

10 BIGGEST IMPACTS ON EARTH

The largest craters that can be found on the surface of our planet

Beaverhead
Diameter: 60km
Age: 600 million years
On the border of the US states of Montana and Idaho you'll find this crater. The only remaining visible evidence for this crater comes from rock that was shocked by the impact force.

Sudbury Basin
Diameter: 130km
Age: 1.8 billion years
The third largest impact crater is the Sudbury Basin in Ontario, Canada, thought to have been caused by a meteorite up to 15km across.

Manicouagan
Diameter: 100km
Age: 215 million years
This ring-like lake found in Quebec, Canada, is thought to have been formed by a meteorite about 5km across hitting Earth.

Chicxulub
Diameter: 180km
Age: 66 million years
Believed to have wiped out the dinosaurs, the Chicxulub crater on the Yucatán Peninsula in New Mexico is the second largest impact crater on Earth.

DID YOU KNOW? *The only person to ever be hit by a meteorite in recorded history was Ann Hodges from Alabama in 1954*

Kara
Diameter: 65km
Age: 70 million years
This crater in Russia may once have been 120km across, making it the fourth largest in the world before it was eroded and shrunk to its current size.

Popigai
Diameter: 100km
Age: 35 million years
Found in Siberia, the Popigai crater is the fourth largest in the world. It possibly caused the Eocene-Oligocene extinction event, when many marine organisms died.

Morokweng
Diameter: 70km
Age: 145 million years
An asteroid up to 10km across is thought to have formed this impact crater in the Kalahari Desert near the border of South Africa and Botswana.

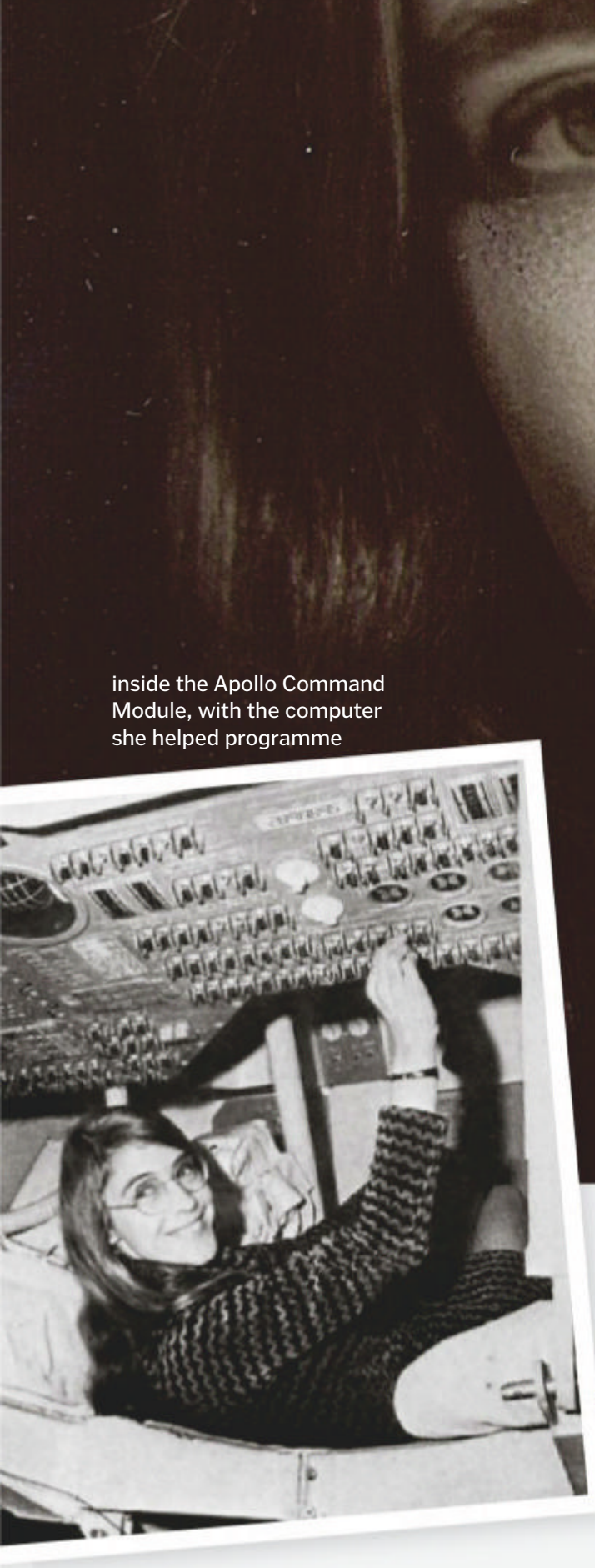
Tookoonooka
Diameter: 55km
Age: 128 million years
Possibly measuring up to 66km across, this crater in South West Queensland, Australia, was first reported back in 1989.

Vredefort Dome
Diameter: 300km
Age: 2 billion years
Found in South Africa, this is the largest known crater on Earth. Although much of it has eroded away, the remaining structure is called the Vredefort Dome.

Acraman
Diameter: 90km
Age: 580 million years
Found in South Australia, this impact crater contains a lake that's 20km across known as Lake Acraman. The discovery of the crater was first reported in 1986.

HEROES OF... SPACE

Margaret Hamilton invented the modern concept of computer software



inside the Apollo Command Module, with the computer she helped programme

A life's work

From maths to the Moon

1936
Born Margaret Heafield in Paoli, Indiana, US, on 17 August.

1958
Graduates with a degree in mathematics and philosophy from Earlham College in Indiana.

1960
Begins working at the Massachusetts Institute of Technology (MIT) developing weather-prediction software.

1961
Starts working on the US Semi-Automatic Ground Environment (SAGE) air defence system at Lincoln Laboratories.

Margaret Hamilton

The software engineer who helped Apollo reach the Moon

By 1986 Hamilton was founder and CEO of her own software company

Three minutes before Neil Armstrong and Buzz Aldrin landed on the Moon in 1969, red and yellow lights began to flash on their craft's control panel. This '1202 alarm' signalled a hardware-related problem with the Eagle lander, putting their decent in jeopardy. They didn't realise at the time, but the astronaut checklist that they had completed before starting the landing procedure had mistakenly told them to set the rendezvous radar switch to the wrong position, causing the craft's central processing unit to become overloaded.

Luckily, the computer's software had detected this issue and after triggering the alarm had quickly prioritised the landing systems, clearing out less important tasks such as the rendezvous radar. The priority display gave the astronauts a go/no-go decision for landing, and with their trust placed in the software code they went on to take one giant leap for humankind.

The software that had saved the day and made this momentous achievement possible was created by a team of computer programmers at the Massachusetts Institute of Technology (MIT), led by 31-year-old Margaret Hamilton. The first contract NASA issued for the Apollo programme was for the development of this guidance and navigation system, but there was no such thing as software engineering at the time. It was still the early days of computing, so everything that Hamilton and her team had learnt was from hands-on training – there were no courses to take or manuals to follow; they had to make it up as they went along. In fact, the term 'software engineering' was coined by Hamilton herself, as she wanted it to be considered a legitimate and respected field in its own right.

Incredibly, Hamilton's role in the Apollo programme almost didn't happen, as after moving to Boston with her husband she had originally planned to study abstract mathematics at Brandeis University. However, when she was offered a job at MIT programming weather-predicting software her life changed course entirely. She went on to become director of the Software Engineering Division at MIT and later founded her own software company, Hamilton Technologies, Inc.

When working on the Apollo programme Hamilton focused on the detection of system errors and recovery programmes. Her priority displays communicated in real time with the astronauts, warning them of any emergencies and recovering information in the event of a computer crash. With lives at stake it was crucial for her software to be ultra-reliable, and her hard work certainly paid off in those tense few moments before Apollo 11 touched down.

NASA was so impressed with the robustness of her software that it decided to us it on all manned Apollo missions and adapted it for use on Skylab, the Space Shuttle and the first digital fly-by wire systems in aircraft, replacing manual flight controls.

THE BIG IDEA

From NASA nerd to programming hero

Based on her experience writing flight computer software for the Apollo programme, Margaret Hamilton went on to design the Universal Systems Language (USL) – a completely new approach to software programming. Before USL, most systems would try to cure problems 'after the fact', but Hamilton took a radical new approach. Her system predicted and prevented problems before they were encountered instead. This has given software developers a language they can use to solve problems previously considered next to impossible to solve, resulting in ultra-reliable, lower-risk programmes. Many computer-based technologies today owe their existence to Margaret's genius.

Hamilton standing next to a stack of the Apollo Guidance Computer source code she helped create

5 THINGS TO KNOW ABOUT... MARGARET HAMILTON

1 She has her own Lego figure
In October 2017 Lego announced its new 'Women of NASA' set featuring figures of Nancy Grace Roman, Sally Ride, Mae Jemison and Margaret Hamilton, complete with her stack of code.

2 She helped design a US air defence system
While at MIT she helped design the US Semi-Automatic Ground Environment (SAGE) air defence system, writing software that would work to identify enemy aircraft.

3 She took her young daughter to work with her
As a working mother Hamilton had to take her daughter Lauren with her to the lab on weekends and evenings. She slept on the office floor while her mother worked on Apollo.

4 She saved Apollo 8 and 12
Hamilton fixed Apollo 8's computer when an astronaut mistakenly wiped its navigational data, and her software restarted the mission functions when lightning hit Apollo 12 before lift-off.

5 Her code was hardwired
Hamilton's Apollo code was shipped to seamstresses, who would thread copper wire through magnetic rings, each wire representing a 'word' of the programme.

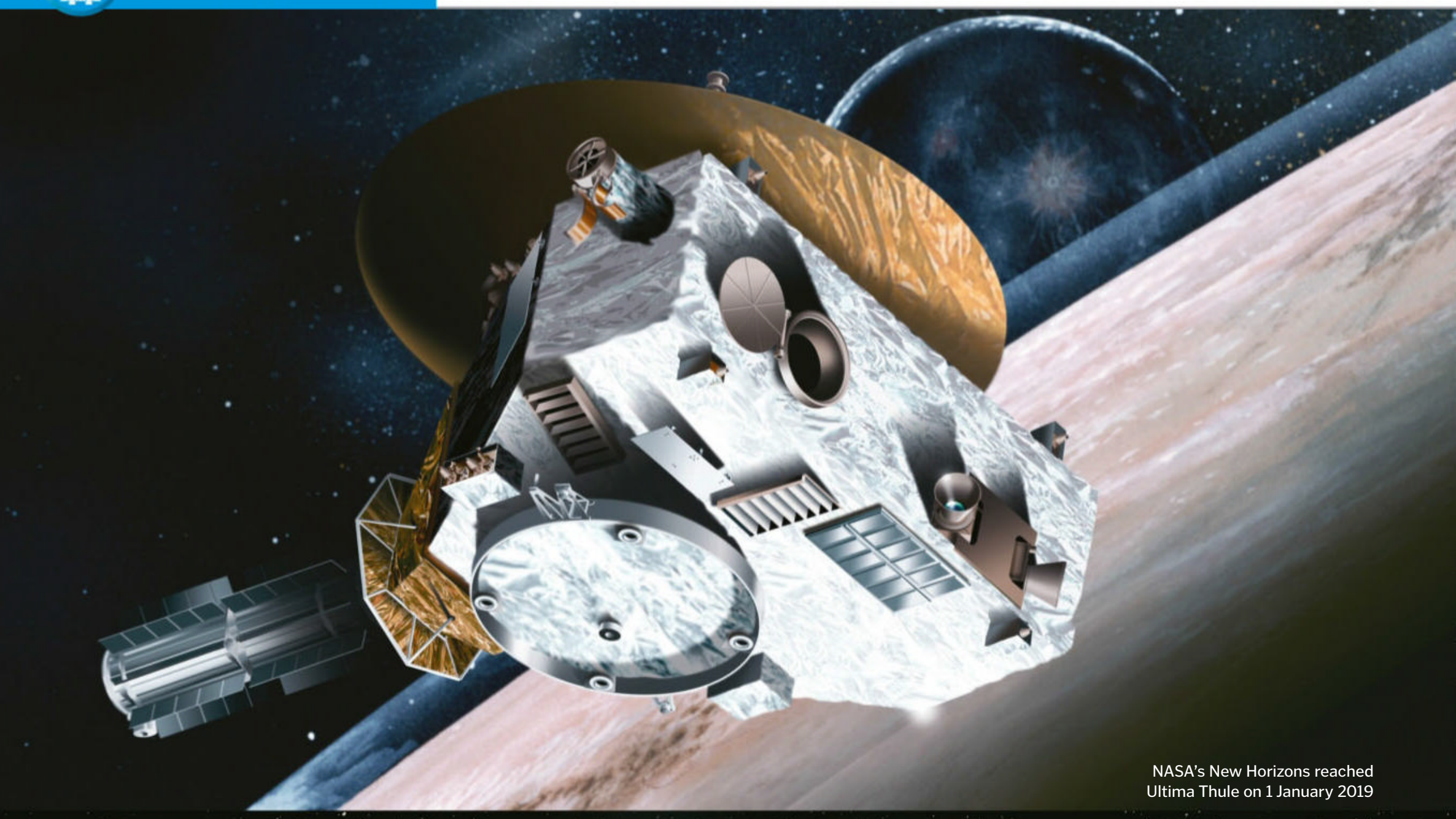
1965
Leads the team that created the onboard flight software for NASA's Apollo command and lunar modules.

1976
Co-founds the Higher Order Software (HOS) company and becomes its CEO.

1986
Becomes founder and CEO of Hamilton Technologies, Inc., a company developed around her Universal Systems Language (USL).

2003
Receives NASA Exceptional Space Act Award and $37,200 (approximately £29,000) – the largest sum of money awarded to any individual by NASA up until that point.

2016
Awarded the Presidential Medal of Freedom by Barack Obama for her work on Apollo.



NASA's New Horizons reached Ultima Thule on 1 January 2019

Radioactive space power

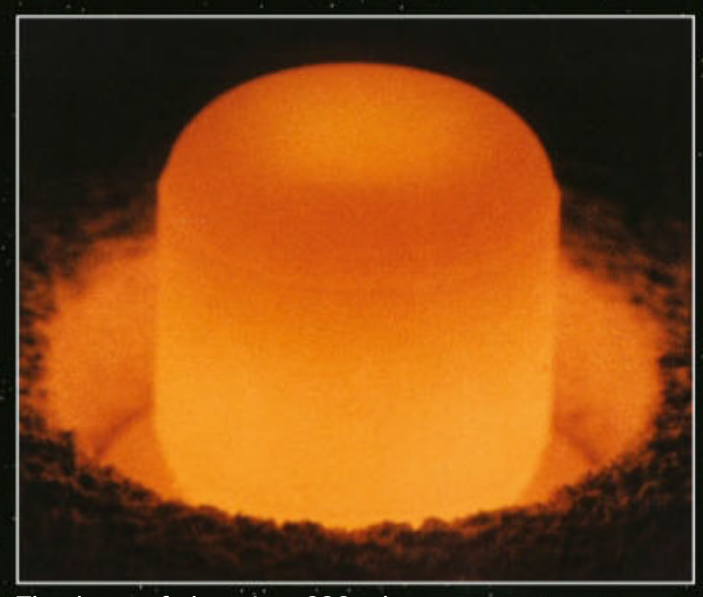
How spacecraft turn radioactive plutonium into electricity with which to explore the Solar System

NASA's New Horizons spacecraft has been exploring the Solar System for over 13 years, and it hasn't refuelled once. There are no petrol stations in space. It's already captured images of Pluto's icy heart and now it's cruising through a doughnut-shaped ring of ice called the Kuiper Belt. Billions of miles from the Sun, the light there is more than 1,000-times dimmer than it is here on Earth, so solar panels aren't an option. Instead, the onboard scientific instruments rely on radioactive fuel.

When New Horizons left Earth it carried approximately 11 kilograms of radioactive plutonium dioxide contained inside a piece of kit called a radioisotope thermoelectric generator (RTG). The plutonium forms the heart of a nuclear battery that is hooked up to temperature sensors called thermocouples.

Each thermocouple has two metal plates, joined at both ends to form two junctions. The outer junction faces towards the chill of space while the inner one sits against the decaying nuclear fuel. As the plutonium decays it releases alpha particles, generating heat; before launch the New Horizons RTG reached a scorching 245 degrees Celsius. This heat creates a temperature difference between the junctions of the thermocouples, and this sets an electric current in motion.

With a brand-new fuel cell, the RTG generated 245 watts of power at launch. Now, after 13 years, the battery is still going strong. With no moving parts the generator never wears out; it will keep going until the nuclear fuel is completely spent. When New Horizons reached Pluto, the temperature of the battery dropped to around 208 degrees Celsius, but it's still making 190 watts of power. That's more than enough to supply New Horizons' seven scientific instruments, each of which only uses between two and ten watts.



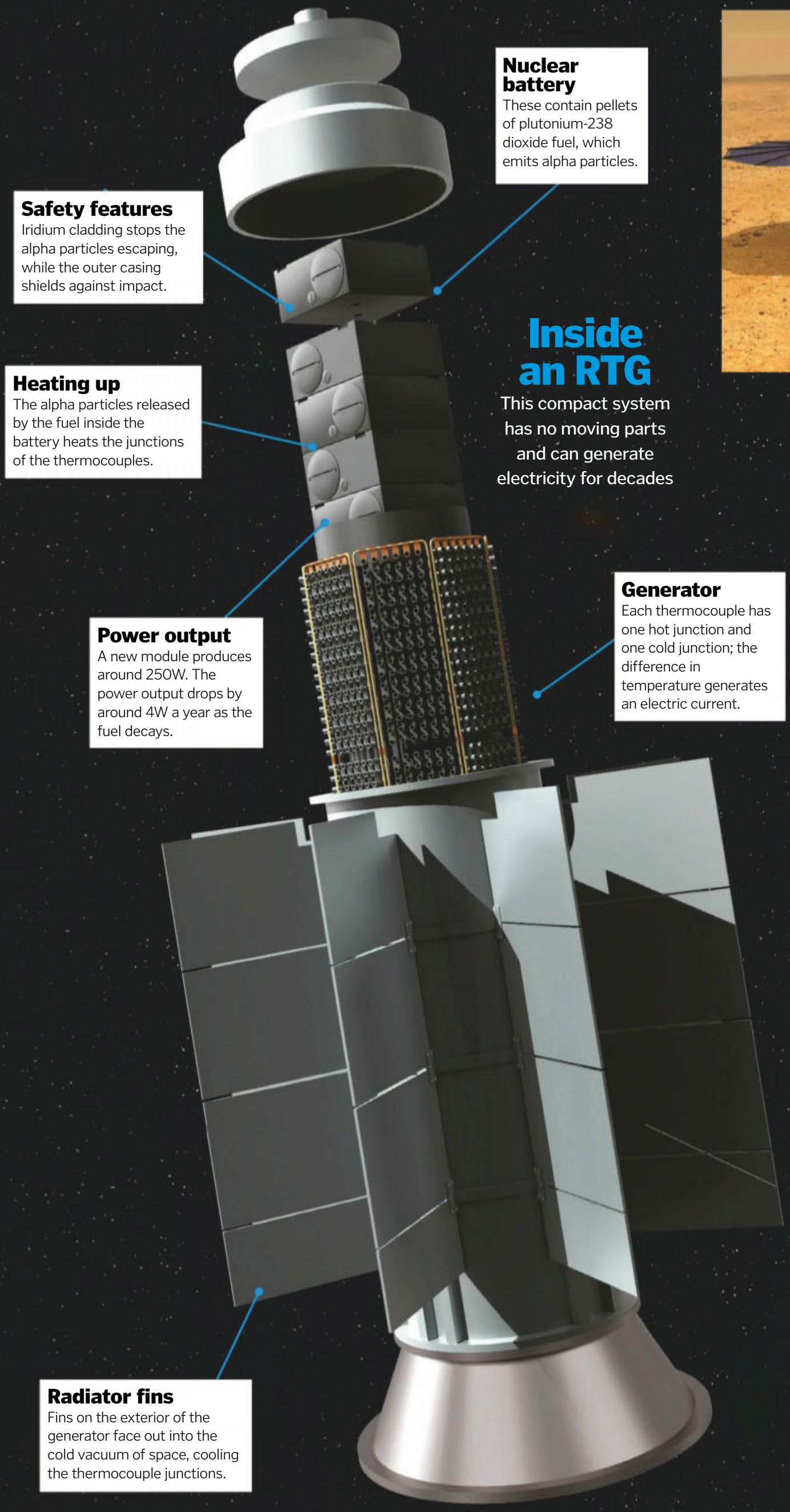
The decay of plutonium-238 releases so much heat that the fuel pellets glow

NASA's Voyager 1 launched in 1977 and still has RTG power today

DID YOU KNOW? *A small number of people have pacemakers powered by the radioactive decay of plutonium-238*

Inside an RTG

This compact system has no moving parts and can generate electricity for decades



Nuclear battery
These contain pellets of plutonium-238 dioxide fuel, which emits alpha particles.

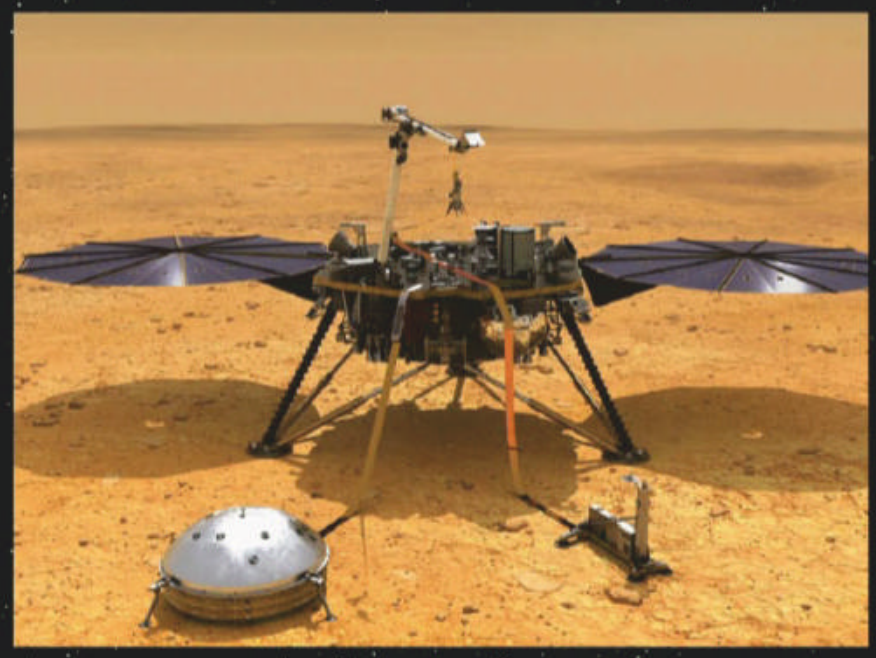
Safety features
Iridium cladding stops the alpha particles escaping, while the outer casing shields against impact.

Heating up
The alpha particles released by the fuel inside the battery heats the junctions of the thermocouples.

Power output
A new module produces around 250W. The power output drops by around 4W a year as the fuel decays.

Generator
Each thermocouple has one hot junction and one cold junction; the difference in temperature generates an electric current.

Radiator fins
Fins on the exterior of the generator face out into the cold vacuum of space, cooling the thermocouple junctions.



While very reliable, no RTG has yet achieved an efficiency above ten per cent

Plutonium-238

Space fuel needs to check three critical boxes before it can be approved for use: it must be safe, it mustn't interfere with scientific instruments, and it has to last. According to NASA, only one chemical is up to the job – ceramic beads of plutonium-238. It only takes a small amount to generate a lot of power and it has a half-life (the time it takes for half of the atoms to decay) of 87.7 years. The alpha particles released by the fuel supply enough heat to keep the thermocouples warm for decades, but they don't penetrate like beta, gamma and neutron radiation. This helps to protect the delicate onboard instruments. Making plutonium-238 involves bombarding neptunium-237 with neutrons inside nuclear reactors. This can be tricky, but it stays solid if there's an accident and it doesn't trigger the dreaded chain reactions seen in nuclear power plants or nuclear warheads.

Oak Ridge National Laboratory, Tennessee, US, started producing plutonium-238 in 2015

"When New Horizons left Earth, it carried 11 kilograms of radioactive plutonium dioxide inside an RTG"

Protecting Earth from the Sun

How does our atmosphere filter out the deadliest parts of solar radiation?

The Sun serves as our planet's celestial lifeline, playing a vital role in the sustainability of our ecosystems. However, without the Earth's atmospheric bubble the Sun's rays would also flood our planet with radiation. Along with the Sun's emitted visible light, other electromagnetic radiation such as ultraviolet light reaches Earth, though not at levels fatal to most life. This is thanks to several layers within the atmosphere filtering the deadliest forms before they reach Earth.

There are three ways our atmosphere does this. One is scattering, whereby radiation is redirected in multiple directions when it collides with smaller atmospheric particles. Another of the atmosphere's filtration methods is reflection, which is typically when water molecules in clouds reflect wavelengths back out into space. The final defence is absorption, most prolifically at the ozone layer at the stratosphere. Before reaching the ozone layer, radiation from the Sun is absorbed in different levels through the atmosphere, but the type of radiation most absorbed by the ozone is a wavelength of ultraviolet light called UV-B.

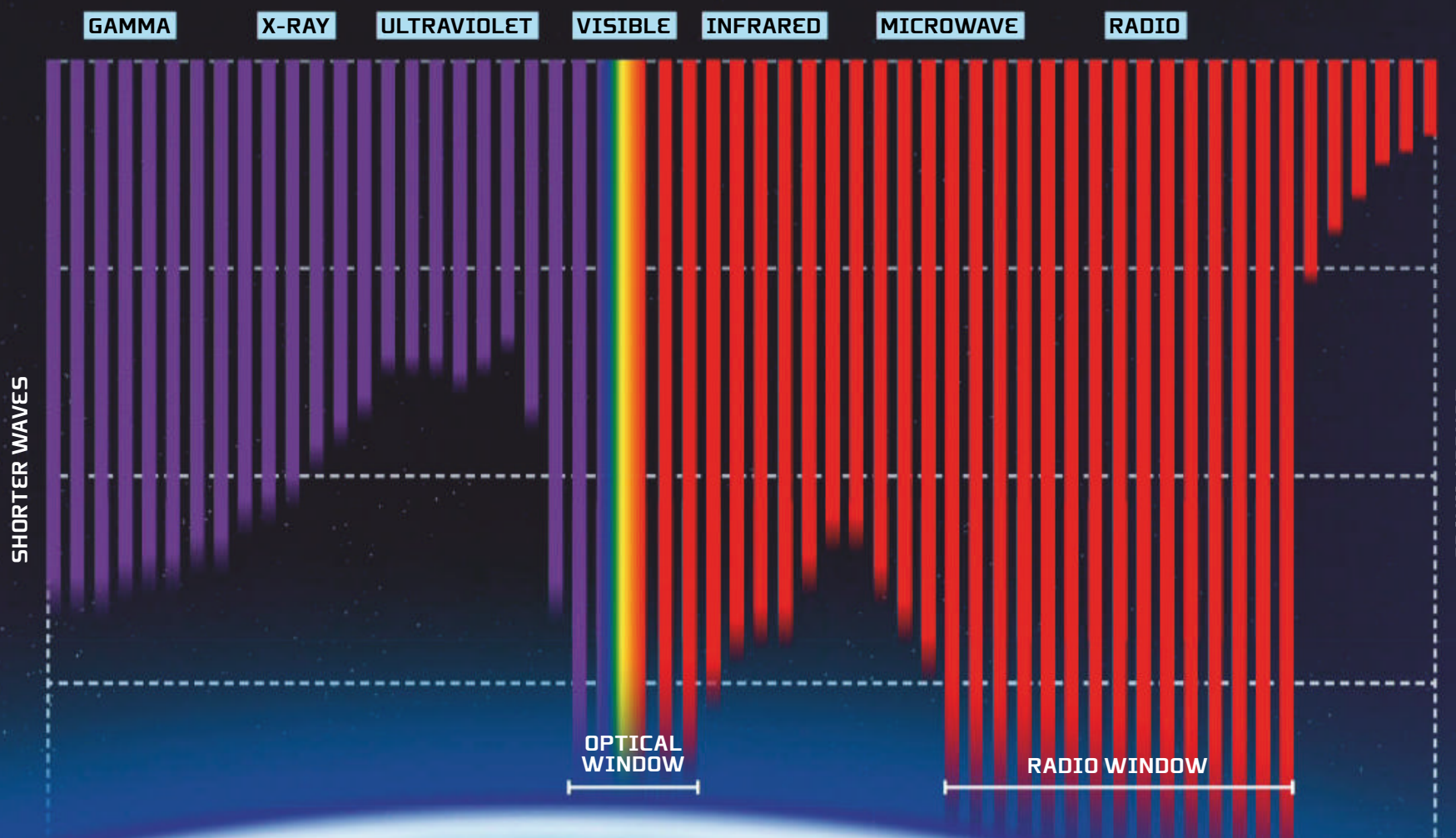
Ozone is a molecule made up of three oxygen atoms that are bound together. When the high-energy wavelengths of UV reach this oxygen layer the energy knocks away one of the oxygen atoms from ozone and, in turn, the radiation is absorbed. This free oxygen atom then goes on to bind with other free oxygen atoms, forming more ozone as the cycle continues.

Thermosphere
85–600km altitude
Made up predominantly of oxygen, nitrogen and helium, this layer is responsible for absorbing the vast majority of high-energy, short wavelengths (such as X-rays) before they reach Earth.

Mesosphere
50–85km altitude
More X-ray and UV radiation is absorbed before reaching the ozone layer in the stratosphere.

Stratosphere
14.5–50km altitude
Here the ozone layer takes on the task of absorbing and scattering most of the deadlier types of radiation.

Troposphere
0–14.5km altitude
As the last line of defence, cloud formations in this layer can reflect UV-B that has passed through the ozone layer.



Continuous cycle
Ozone is constantly being formed in a cycle created by the interaction with electromagnetic radiation.

Inside the Earth's atmosphere

Which forms of radiation make it to the surface and which are blocked by our atmospheric buffer?

Space shield
The Earth's atmosphere is designed to filter out the penetrating radiation of the Sun.

Seeing deep into space

Though the Earth's ozone layer keeps its inhabitants safe, it can also be an obstacle when we want to peer out into space. By its very nature, the ozone layer blocks incoming electromagnetic radiation such as X-rays and gamma rays emitted by the Sun and other stars.

X-rays, for example, are high in energy and have a short wavelength, and when these reach atoms such as oxygen in the outermost layer of the atmosphere the photons that make up the wave knock out one of the atom's electrons, replacing it so that it never reaches deeper into the atmosphere. Therefore, to get a better picture of intergalactic activity, X-ray-detecting telescopes are sent beyond Earth's atmosphere. NASA's Chandra X-Ray Observatory, for example, is a satellite telescope currently orbiting Earth that detects interstellar events.

The blue and purple rings in this image are X-rays emitted from a supernova

DEADLY PARADISE

What makes Madidi National Park one of the most diverse yet dangerous places in the world?

Words by **Victoria Williams**

In 1981, young Israeli backpacker Yossi Ghinsberg set off into an uncharted area of the Bolivian Amazon with two acquaintances and a complete stranger. The new addition to the group, a mysterious man named Karl Ruprechter, claimed to be a geologist and gold miner and enthralled them with stories of an indigenous tribe and undiscovered gold. Unable to resist the temptation of adventure and riches, they ignored the warnings of local people and followed him by plane and boat into the jungle.

After two weeks of walking, the group had achieved nothing besides getting lost, eating all their food supplies and arguing. They decided to split up, with Ghinsberg and American photographer Kevin Gale building a raft and continuing, while Swiss teacher Marcus Stamm – who had developed trench foot and had grown weak after refusing to eat the monkeys the other men shot – attempted to return to civilisation with Ruprechter. When strong currents smashed their raft against a rock, Ghinsberg was separated from Gale and spent the next three weeks alone fighting for survival.

Ghinsberg could hardly have been lost in a worse place. He was travelling through an area of the Amazon that now belongs to Madidi National Park. Established in 1995, the park covers 18,958 square kilometres and is believed to be the most biologically diverse place in the world. With its neighbouring reserves and parks, it's part of one of the world's largest protected areas. However, with diversity comes danger; during his three-week ordeal Ghinsberg encountered countless threats, from fire ants to a prowling jaguar.

Madidi National Park is teeming with life, from the adorable to the lethal. It's home to around 270 types of mammal, almost 500 different fish, over 200 species of amphibian and about the same number of reptiles. Insects are harder to count, but it's currently estimated that some 120,000 species flit and crawl their way through the forest. Perhaps most staggeringly, around 1,200 species of bird – over a tenth of all worldwide bird species – can be found in Madidi.

How this paradise was protected

Ten years after Yossi Ghinsberg's ordeal he returned to the area of the Amazon that nearly claimed his life to thank the locals who helped him. He secured a grant and built a solar-powered ecolodge then spent three years teaching the locals how to manage it. He was also one of the main drivers in the designation of the area as a national park.

Someone else who was instrumental in the creation of Madidi was Rosa María Ruiz. Founder of an organisation called Eco-Bolivia, she fought for the park's conservation for more than two decades. She brought the area into the spotlight again in 2000 when she led a team from National Geographic through the region, showing them what would be lost if a proposed dam went ahead. To this day she continues her work, now focusing on sustainable tourism in the park.

Chalalan Ecolodge was established by Yossi Ghinsberg and is run by local Bolivian people

Animals like this spider monkey must be constantly alert to avoid becoming a predator's next meal

Madidi National Park was established on 21 September 1995

Botanists and zoologists flock to the park in the hopes of spotting just a few of these species, and expeditions have uncovered new species found nowhere else, like the Madidi titi monkey.

Not all of Madidi is covered by a canopy; the huge area designated as a national park reaches from the icy slopes of the Andes to the lush rainforest, with climates ranging from cold and temperate to tropical. A visit to Madidi is a step back in time and a chance of real adventure – there's no internet connection or phone signal, and the lodges in the heart of the forest are many kilometres from the nearest town. Even getting to the park is a challenge, requiring a 40-minute flight or a winding 20-hour bus journey from La Paz to Rurrenabaque, a small town at the edge of the Amazon known as the gateway to Madidi. These journeys can become even more complicated in the rainy season, when torrential downpours ground flights and wash away the mountain roads. If they make it to Rurrenabaque visitors can explore Madidi on foot or by boat, led by guides able to spot signs of trouble that would go unnoticed by outsiders.

Madidi, renowned for being as dangerous as it is stunning, is now itself under threat. The building of a 'megadam' across the Bala Gorge was first proposed in 1998 – the western edge of the gorge is within the boundaries of Madidi and the dam would flood around 2,000 square kilometres of the park, displacing both wildlife and local people. The initial plans were abandoned, but the project was revived in 2007. President Evo Morales hopes to construct the megadam in the next ten to 15 years and turn Bolivia into South America's leading producer of hydropower, but the idea has been met with fierce resistance from indigenous and environmental groups. The forest holds huge importance for many people – both those who call it home and those who have immersed themselves in its wilderness for a few weeks.

Yossi Ghinsberg was lucky; despite falling in swamps, losing all the skin on his feet, starving and beginning to hallucinate, he was rescued from the Amazon after Kevin Gale drifted down the river to a village and asked the local people to help him form a search party. The fate of the other two remains a mystery, as they were never seen again. Ghinsberg has told his story many times, and still people are drawn to the forest. Madidi National Park is a place of breathtaking beauty, but danger waits around every turn for the reckless traveller.

Not all of Madidi's residents are dangerous. Some, like the capybara, are rather endearing

DEADLY WILDLIFE

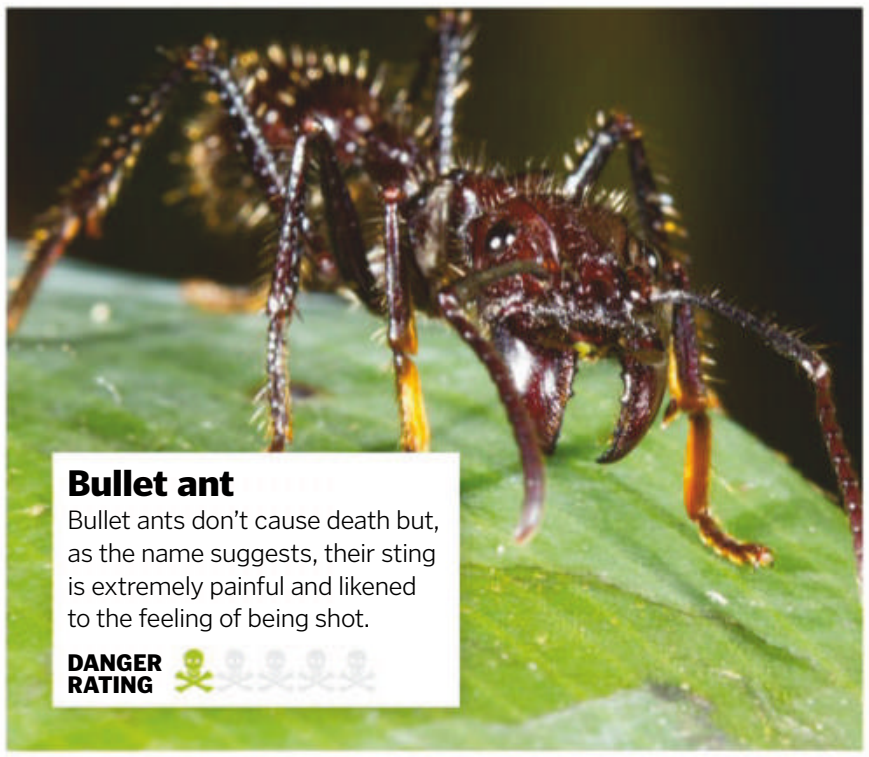
Which of Madidi's animals are just a nuisance and which are a real worry?

Giant otter
Although they usually keep away from people, giant otters are fierce and can take down caimans, so they're best avoided.
DANGER RATING

Piranha
Piranhas have sharp interlocking teeth and fearsome reputations, but they'll usually only eat people if they're already dead.
DANGER RATING

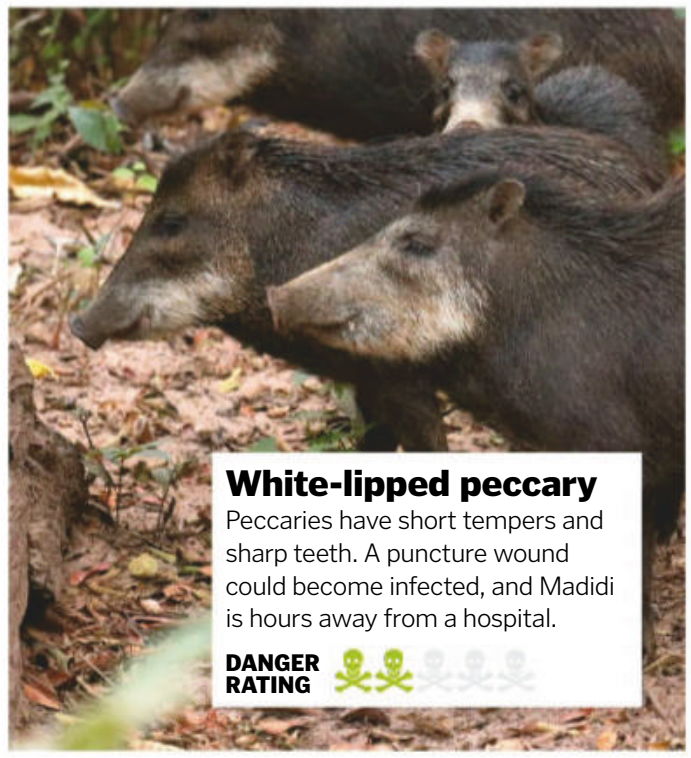
Human botfly
Developing larvae live in and feed on human flesh. They're a common nuisance in the park but rarely a real danger.
DANGER RATING

Jaguar
Jaguars rarely attack humans, but when they do it's often fatal as their sharp teeth puncture the skull or neck.
DANGER RATING



Bullet ant
Bullet ants don't cause death but, as the name suggests, their sting is extremely painful and likened to the feeling of being shot.

DANGER RATING



White-lipped peccary
Peccaries have short tempers and sharp teeth. A puncture wound could become infected, and Madidi is hours away from a hospital.

DANGER RATING

Electric eel
Adult electric eels deliver a strong shock, potentially strong enough to cause heart failure or stun a person long enough to lead to drowning.

DANGER RATING

Poison dart frog
Some species of dart frog have enough toxins stored up to kill several fully grown men, secreting the poison through their skin to keep themselves safe.

DANGER RATING

Anaconda
With their strength and crushing power anacondas are a serious threat to their prey, but they rarely bother with humans.

DANGER RATING

5 FACTS ABOUT MADIDI NATIONAL PARK

1 It's not always hot
The tropical parts of Madidi average 33 degrees Celsius for most of the year, but Arctic winds in June and July can cause temperatures to plummet to just seven degrees.

2 Animals will come to you
The dry season is the most popular time to visit Madidi; animals are drawn to lakes and rivers in search of water, making them much easier to spot.

3 There's some serious rainfall
Being largely tropical rainforest, much of the national park experiences extremely heavy rainfall – usually between 80 centimetres and four metres in a single year.

4 Many people call it home
Around 50 indigenous communities live within the park. They belong to six different tribes and still practise many of their ancient traditions despite having adopted some modern ways and a variety of technology.

5 Insects aren't just annoying
One of the most dangerous animals in the park is also among the smallest: the mosquito. Malaria is a risk throughout the Amazon, with visitors encouraged to remain covered at all times.

Black caiman
The black caiman is the largest and most dangerous of all the crocodilians, known to attack and kill humans.

DANGER RATING

Older pieces of ambergris are lighter in colour due to the process of oxidation that occurs in the ocean

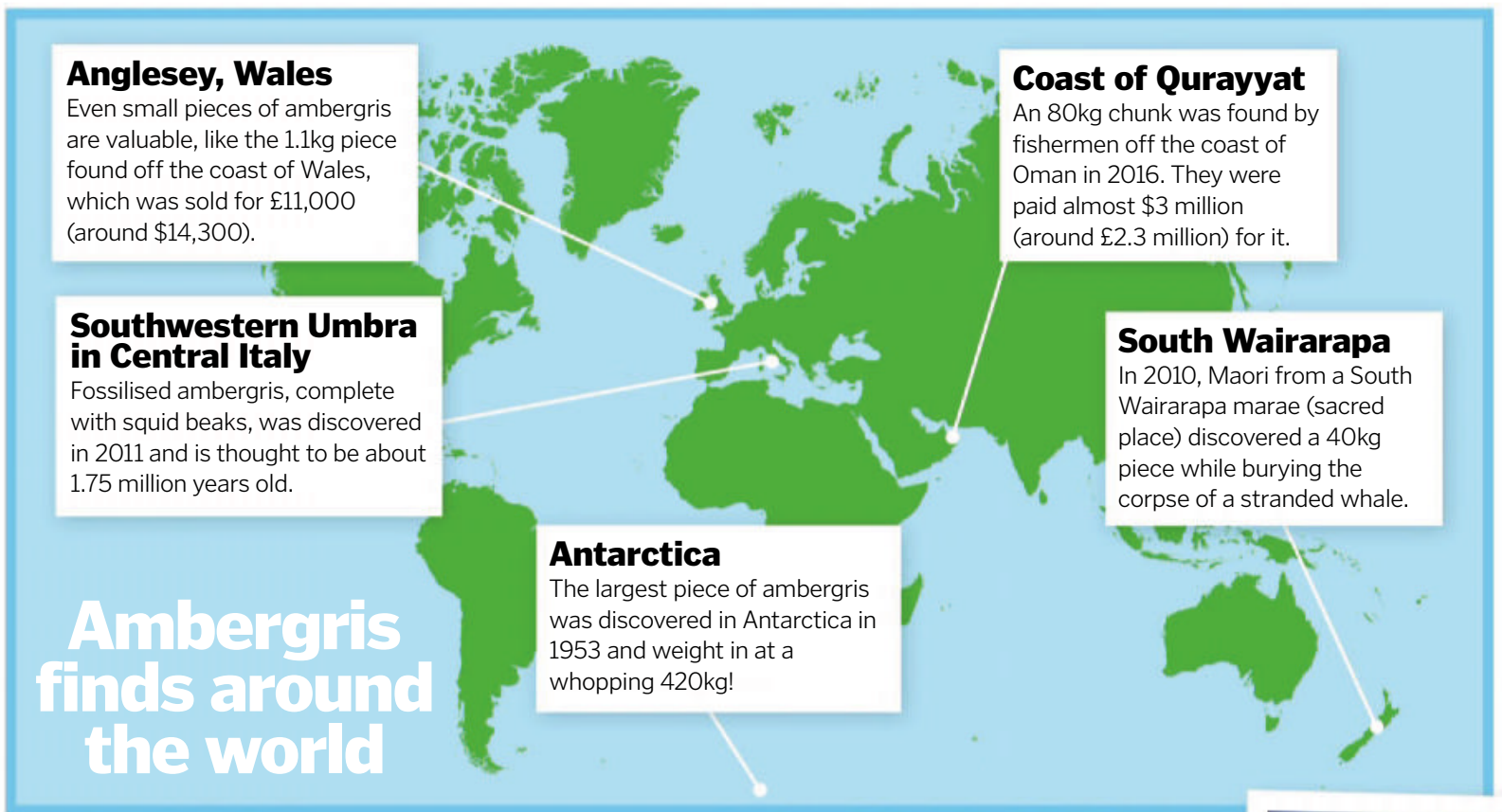
Turning poo into perfume

There's a secret scent in your favourite fragrance that started life as a smelly lump of whale ambergris

When walking along the beach, if you're really lucky you might be able to find a waxy white substance that is nearly as valuable as gold. It's called ambergris, and we have used it throughout human history as a perfume scent, in traditional medicines and even as a spice. But the origin of ambergris was shrouded in mystery for thousands of years until researches realised it is actually a clump of sperm whale faeces.

Sperm whales have an insatiable appetite. They can gobble down up to a ton of food every day, and included in their behemoth banquet are squids. Although most of a squid's body is soft and fleshy, they have thorny beaks that sperm whales are not able to digest. They are usually vomited back into the ocean every few days to protect the whale from trying to pass the sharp edges through their intestines. However, an estimated one in 100 sperm whales are not so lucky. For these whales, some of the beaks get stuck. As faeces, intestinal worms and squid eyeballs accumulate the debris becomes a sticky brown blockage. The whale's sphincter is not designed to pass solid faeces and it gets stuck. Whales can survive several years, or even decades with the blockage, but eventually the creature can die – either from other causes or, if the ambergris becomes too large, due to the rupturing of the intestinal walls.

As the carcass is eaten by other marine animals the mass is released into the ocean. It will float for years on the surface of the water, and sunlight, salt water and bacteria will cause chemical changes within the ambergris that clean and dry it. This process causes the ambergris to form a pale grey or yellow colour and possess the light, distinctive scent of ambergris.



5 FACTS ABOUT WHAT YOU MAY FIND IN A RARE LUMP OF SPERM WHALE FAECES

1 Beaks
Squid beaks that have become entrapped in the whale's intestines comprise most of the mass.

2 Ambrein
This can be separated from the substance by heating raw ambergris in alcohol, from which the perfume odour components ambroxide and ambrinol can then be made.

3 Intestinal worms
Parasitic worms are common in sperm whales. They get tangled into the squid beaks and contribute to the formation of ambergris.

4 Wax-like substance
Sperm whales naturally excrete a waxy substance that coats the sharp objects that the animal tries to digest.

5 Different colours
Ambergris changes colour as it is oxidised by the sea and air over a period of several years. Between black and white, the colours range from grey to brown.

Ambergris in perfume

Despite its rather disgusting origins, ambergris is still used in perfume today. It is valued because of its unique smell and its suitability as a fixative, which make scents linger longer and intensify the aroma of the perfume. The distinctive aroma is described as a sweet marine musk, which is caused by the active ingredient triterpene alcohol ambrein. Obtaining the ambergris is not easy, and perfume manufacturers have to rely on buying pieces that are found on beaches or inside fishing nets. In fact, it's so rare that one gram of the stuff is estimated to cost around $20 (approximately £15) per gram, perhaps more.

Although many synthetic versions of this chemical are used in modern perfumes, high-end manufacturers (including famous names such as Chanel and Givenchy) continue to use ambergris because of its classic and historical qualities.

Sperm whales are protected, and hunting the species is illegal, so ambergris is only obtained by beach combing and other non-intrusive methods

CORGI®

Eddie Stobart

TY86659
Eddie Stobart Box Lorry

TY86646
Eddie Stobart Curtainside Truck

TY86650 Eddie Stobart Skeletal Container

TY86649 Eddie Stobart Fridge

TY86651
Eddie Stobart Drop Bar Truck

TY86647
Eddie Stobart Tanker Truck

A model delivery

Corgi's Eddie Stobart Collection is a series of quality die-cast and plastic 1:64 scale toy trucks suitable for children aged five and over. Each truck has a detachable trailer and carries an authentic livery of some of the most popular trucks on Britain's roads today.

To order call 01843 233 512
(Telephone order lines are open 9am-5pm Monday to Thursday and 9am-3pm on Friday)
Alternatively go to **www.corgi.co.uk**
or visit your local Corgi stockist!

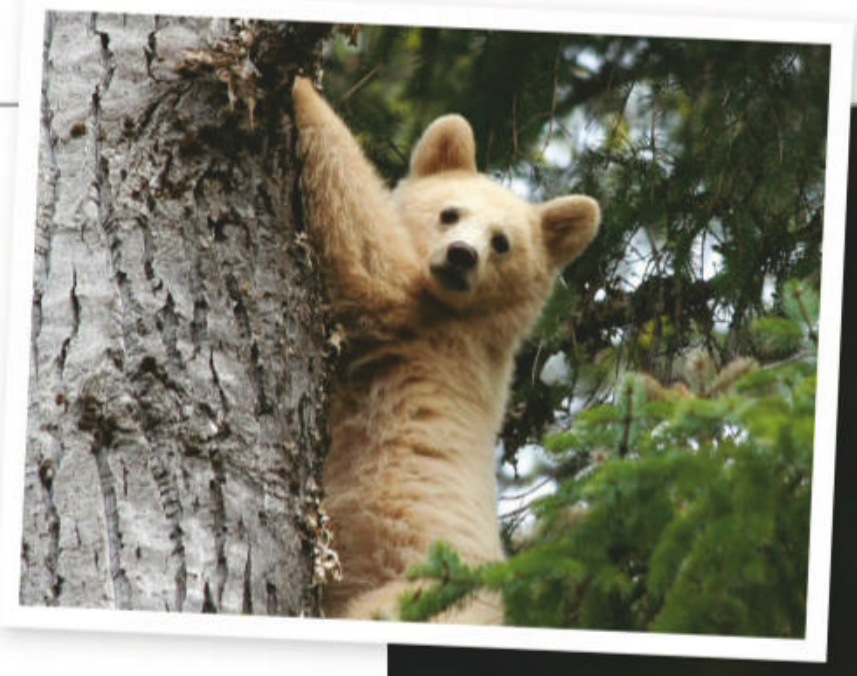
YouTube /officialcorgi @corgi /corgidiecast

AFTER WORKING WITH HIS FATHER IN agriculture, Edward Stobart started his haulage career using his father's delivery trucks and formed Eddie Stobart Haulage Company in 1976. From this point, Edward was able to grow his business into Britain's most recognised haulier, employing over five thousand people.

Corgi is proud to present a range of fantastic Eddie Stobart models. Whether you are buying for a young collector starting out, or adding to your existing collection.

What is a spirit bear?

How these pale-pelted mammals turn their colouring to their advantage



Due to the recessive nature of the spirit bear gene mutation, two black bears with the gene can produce spirit bear offspring

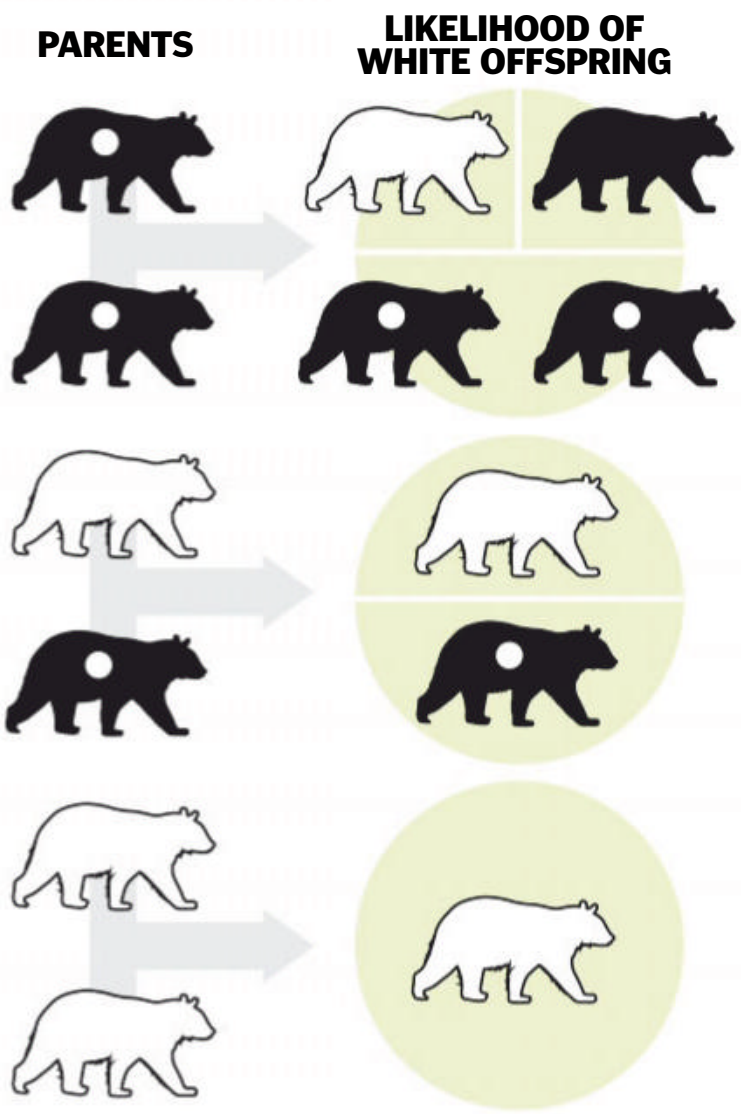
If you go down to Canada's Great Bear Rainforest, you're sure for a big surprise. Located at British Columbia's northwestern coast, Canada, are dense forests spanning 21 million acres. Aptly named the Great Bear Rainforest, this Amazon of the north is home to some truly unique bears. American black bears are among the most common species, however only in the Great Bear Rainforest have these bears evolved with a different coloured coat. They are known as Kermode, or 'spirit', bears.

Traditionally sporting black fur, it's estimated that there could be as few as 100 left. The change in colour is thanks to a rare genetic variation in a gene called MC1R, which codes for a protein that sits on the surface of melanocytes, cells that produce melanin for colouration. This mutation in the gene is what causes the melanin to appear white instead of black. Though these bears are often mistakenly thought of as being albinos - when there is a lack of melanin in the fur and eyes - this is not the case, as like black bears, they have a dark nose and paws.

Researchers have found that thanks to their unusual appearance they are 30 per cent more effective in hunting during the daytime compared to their darker counterparts. This efficiency may have been one of the reasons they have maintained their genetic lineage since the mutation was first expressed. It is thought that due to the isolated nature of the forests the gene has not spread further than the bears residing in Great Bear Rainforest. Another explanation for their continued presence has been selective mating, meaning that spirit bears have a preference for other spirit bears and so the genetic mutation is passed down from generation to generation.

Creating a spirit bear

What is the likelihood of a bear cub being a black or spirit bear?



25%
In the event two black bears with the spirit bear recessive gene mate, there is a 25 per cent chance their offspring will be a spirit bear, a 25 per cent chance of being a black bear without the recessive gene, and a 50 per cent possibility of a black bear with the recessive gene.

50%
Should a spirit bear and a black bear carrying the recessive gene produce offspring, there is an even chance of them producing a spirit or black bear with the recessive gene.

100%
A paring of two spirit bears would guarantee another spirit bear offspring.

Bear profile

SPECIES
Kermode bear
Ursus americanus kermodei
SIZE
Weight: 80–200kg
Length: 1.2–1.9m
HABITAT
Found only in the Great Bear Rainforest, these bears build their winter dens beneath the forest's dense canopy.
DIET
A spirit bear's main source of food is fish, in particular Pacific salmon. Like all black bears, spirit bears are omnivores and therefore will eat fruits, nuts, plants and even carrion (rotting flesh) when fish is in short supply. Scientists think their white coats act in their favour when hunting for fish during daylight as they are harder for the fish to spot above the water.
LIFESPAN
25 years in the wild
THREATS
The biggest threat to this unique bear is disruptions in the coastal ecosystem. Declining salmon populations, tree logging and migrating grizzly bears could threaten this isolated species.

Spirit bears feast on the flesh of fresh pacific salmon during spawning season

DID YOU KNOW? *Native Americans call the spirit bear 'moskgm'ol', which means 'white bear'. They see these bears as sacred*

Spirit bears can only be found in the Great Bear Rainforest in British Columbia, Canada

A guide to bird beaks

Whether they're plucking fish from the ocean or tearing flesh from bone, evolution has given birds exactly the right tools for the job

When Charles Darwin encountered finches on the Galápagos Islands he noticed that while the birds all looked similar, they had distinctly different beaks. Through patient study he saw that each species fed on different foods. While the green warbler-finch was snatching insects from branches with its small, slender beak, the vegetarian finch was cracking open tough cactus seeds with a broad, strong beak. These observations helped him to develop his theory of natural selection. Darwin discovered that their feeding adaptations had evolved depending on which foods were more readily available in a bird's environment.

Aerial fishing
Pied kingfisher
(Ceryle rudis)

Birds that dive into the water from metres above the surface rely on a long, spear-like bill to grab onto their slippery fish prey.

Chiselling
White-bellied woodpecker
(Dryocopus javensis)

Long, thin, chiselling bills are strong enough to strike a tree trunk up to 40 times a second to open up holes to reveal bugs under the bark.

Coniferous seed eating
Red crossbill
(Loxia curvirostra)

Birds feeding on seeds from confier trees have beaks with elongated tips that cross over and under the other.

Dip netting
Brown pelican
(Pelecanus occidentalis)

A long, straight upper beak and a lower part that holds a large fold of skin is an adaptation seen in birds that use their beaks to trap fish.

Filter feeding
American flamingo
(Phoenicopterus ruber)

The almost 90-degree downward angle of filter-feeding beaks allows for the bottom half to be submerged to filter out small crustaceans.

Generalist
House crow
(Corvus splendens)

Generalists, like crows, often have a curved upper mandible and a flatter lower mandible, enabling them to feed on a range of food.

Grain eating
Eurasian bullfinch
(Pyrrhula pyrrhula)

The broad, triangular shape of these beaks, as seen in finches, enables the bird to crack into the protective outer coating of grains.

Insect catching
Asian brown flycatcher
(Muscicapa dauurica)

Birds with small and pointed bills typically catch insects, either in flight, directly from trees or by hopping along the ground.

Probing
Ibisbill
(Ibidorhyncha struthersii)

Probing bills are long and thin with a downward curving shape. They evolved in birds who push their beak into mud or soft ground to feed.

Pursuit fishing
Red-breasted merganser
(Mergus serrator)

Some aquatic birds, like ducks, dive below the surface of ponds, lakes, rivers or seas to catch fish in a flat, splayed bill.

Raptorial
Goshawks/sparrowhawks
(Accipiter)

Birds of prey use talons to grasp and kill their prey and then tear off pieces of meat or crack through bones with their sharp, curved beaks.

Scavenging
Lesser yellow-headed vulture
(Cathartes burrovianus)

Similar to the beaks seen in birds of prey, scavenging birds eat from carcasses and have a pronounced hooked end so they can tear at flesh.

Scything
Pied avocet
(Recurvirostra avosetta)

Scything beaks are used by wading birds living in wetlands. These birds sweep their long, thin, upturned bills through the water to catch prey.

Surface skimming
Black skimmer
(Rynchops niger)

Some birds have a thicker, elongated lower mandible that is dragged through water and an upper mandible that snaps shut on prey.

Fruit eating
Keel-billed toucan
(Ramphastos sulfuratus)

Birds that eat large fruit often have bigger bills that allow them to cut the outer skin of their food and then grasp large pieces.

SUBSCRIBE

to **How It Works** and get a

KitSound Cube Portable Bluetooth Speaker*

FREE GIFT worth £19.99

TINY BUT LOUD

The KitSound Cube Portable Bluetooth Speaker is small enough to fit into your pocket and has surprising sound thanks to a passive bass radiator.

FEATURES

The portable speaker is made from solid metal and features 3.5mm line-in connectivity and a play time of six hours.

COLOURS

Choose from three colours: vibrant purple, electric blue or sleek black.

CONNECTION

This speaker also comes with a buddy jack that will enable you to connect to a number of devices for even more volume.

WHY SUBSCRIBE?

- Brilliant value – save money on the cover price
- You'll never miss an issue
- It's delivered direct to your door

Subscribe now

www.myfavouritemagazines.co.uk/hiw/122m

or call 0344 848 2852 & quote HIW122M

PRINT

Six-month subscription to **How It Works** in print, plus a KitSound Cube

£20.50

PRINT & DIGITAL

Six-month subscription to **How It Works** in print & digital, plus a KitSound Cube

£23

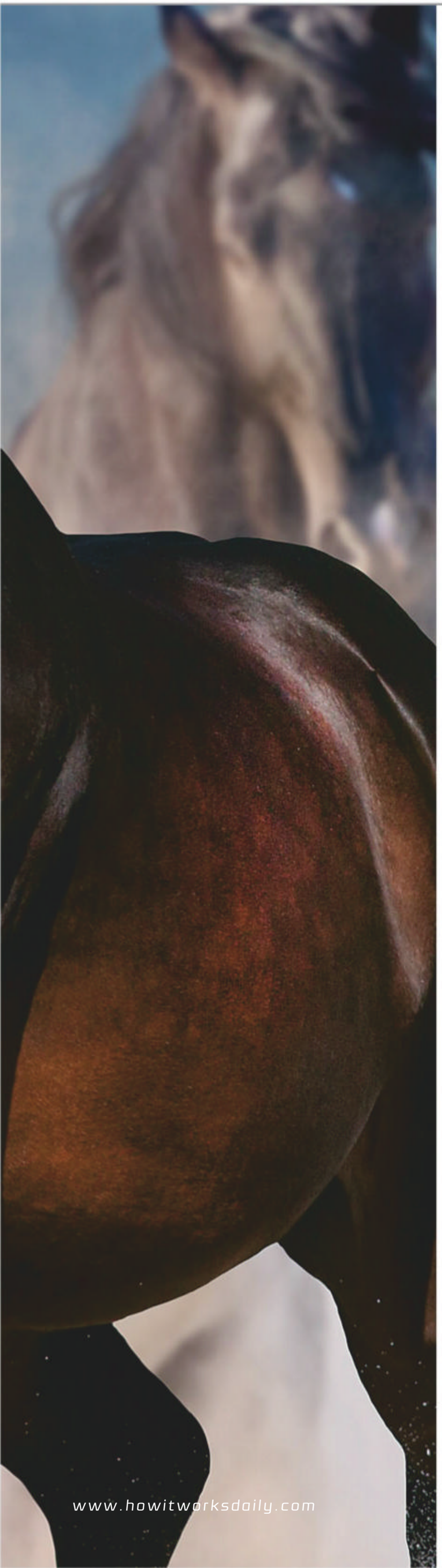
*Terms and conditions: This offer entitles new UK Direct Debit subscribers to pay just £20.50 every 6 months plus receive a Cube Speaker. Gift is only available for new UK subscribers. Gift is subject to availability. Please allow up to 60 days for the delivery of your gift. In the event of stocks being exhausted we reserve the right to replace with items of similar value. Prices and savings quoted are compared to buying full-priced print issues. You will receive 13 issues in a year. Your subscription is for the minimum term specified. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. UK calls will cost the same as other standard fixed-line numbers (starting 01 or 02) or as included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: **www.bit.ly/magterms**. Offer ends 21 March 2019.

Direct Debit Originator's reference 768195

HORSE POWER

Trains to trams, bikes to boats: how horse-drawn transport has withstood the test of time

Words by **Charlie Evans**



Horses have long been used as a means of transport and were originally the most convenient alternative to walking. Horses gave people the ability to move much faster and much farther than on their own two feet. They were used daily, across every continent, until the combustion engine became widespread and motor vehicles were invented. Although the petrol engine was invented by Karl Benz in 1879, it took decades for cars to become popular. The market for cars has boomed since the 1950s, largely replacing the need for horses.

A HISTORY OF HORSEPOWER

Over 4,000 years ago humans started using chariots to cross vast expanses of land. These simple horse-drawn carts are the earliest known horse-powered vehicles. They were so important to their drivers that they have been found buried in the ground as part of chariot burial rites, some of which date back to 2000 BCE.

Horses were first domesticated some 1,500 years earlier than this in the Eurasian Steppes, first to hunt other horses for meat and later to carry people and goods. Since their domestication horses have been used in sports and by the military as well as for transportation. While the industrial revolution gradually reduced our reliance on them, they have helped shaped our own history, and allowed our species to succeed.

> *"Over 4,000 years ago humans started using chariots to cross vast expanses of land"*

STRONG, STURDY AND SPEEDY

Today, the closest to chariot racing you will find is a sport called harness racing. This specialised type of horse racing is popular around the world

Carriages horses in European cities are required to wear 'sneakers', rubber pads that protect their hooves

from France to Australia and Finland to the US. Harness racing involves a horse pulling a small, light two-wheeled cart known as a sulky. The driver usually occupies the front of the sulky and steers the horse from a seated position. Typically, the horses that are used for this type of racing are Standardbreds.

This breed differs significantly from Thoroughbred stock, with proportionally shorter legs and longer body. This physiology means they are able to run without their legs striking the sulky, while their low centre of gravity helps them balance. Almost of all Standardbred horses used in harness racing can be traced to one common ancestor: Messenger, a grey Thoroughbred. Messenger's great grandson, Hambletonian 10, established the new breed line, which still remains one of the most popular in North America today.

Draught horses: gentle giants

While any horse can be trained to pull a vehicle, there are some breeds that have been bred for this purpose. Draught horses are one. Weighing between 1,600 and 2,400 pounds, they were originally bred to pull freight and can still be found pulling carriages around big cities.

The intensive breeding of draught horses has given them so much strength that they are able to pull the equivalent of many times their own body weight over short distances. The most common among this breed include Clydesdale and Shires.

Draught horses remain popular with Amish and Mennonite farmers across the world. Their muscular backs and powerful hindquarters give them huge hauling ability, and their patient temperament makes them easy to work with.

It's no surprise that these giant draught horses can drink up to 95 litres of water a day

Horse-drawn speed machine

What makes a Sulky so sleek, streamlined and lightning-quick?

Harness racing began in the US in the 1800s when postal horses were made to race each other

Seat
A single seat within the cart is occupied by the driver. It is equipped with stirrups for their feet.

Signalling
The driver can use a light whip to signal the horse, either by tapping the horse or making noise by hitting the whip against the shaft of the sulky.

Light wheels
Bicycle wheels with pneumatic tyres designed for carrying the weight of a rider at high speeds are used to carry the cart.

Bike
A light two-wheeled cart is attached to a rope and harness, which is pulled by a horse.

Metal or wooden shaft
The shafts of the cart are usually made of strong but lightweight metals like aluminium or titanium, but they may also be made from carbon fibre or even wood.

Horse-drawn vehicles around the modern world

1 Gharry
This is a traditional horse-drawn carriage for hire in India. The driver is seated at an elevated position.

2 Karozzin
A Maltese carriage drawn by one or two horses, a karozzin is used in ceremonies such as funerals.

3 Tarantass
A four-wheeled Russian horse-drawn vehicle mounted on a long frame, the interior of a tarantass is laid with straw.

4 Vardo
This intricately carved wagon can be used for transport but also acts as a home for many Romani gypsies.

The horses in harness racing either run at a trot, where the horse moves its legs forward in diagonal pairs at the same time, or a pace, where they move both of their front legs forward together, followed by both of their back legs. Pacing is the faster gait of the two. It is partly used for this faster speed, but also because horses are less likely to break their stride due to the use of hobbles. Hobbles are tethers that restrict the full range of movement in a horse's legs and keeps it in a pacing gait. This is important in harness racing because if a horse starts to gallop too soon it can significantly slow the driver, as the horse must be stopped and slowed until it can regain the correct gait.

LEISURE HORSE TRANSPORTATION

Practical and sporting needs aside, many modern horse-powered vehicles exist as a leisurely mode of travel, offering people a unique and sometimes luxurious experience of cruising down a canal or exploring old railways with the company of a horse.

Horse-drawn canal barges are another form of transport that is still used today. They were once a popular transportation method in England and across the waterways of Europe. While they are no longer used practically, various places still use this traditional transport method to demonstrate how they once worked and give passengers an enjoyable ride out in nature along the river. Two people are required to operate such a vehicle; one responsible for steering and keeping the boat in deep water and the other to focus their efforts on driving the horse.

Horse-drawn barges were functional and faster than other alternatives before engines were widely available, but they were inconvenient, particularly if you were unlucky enough to encounter another horse-drawn barge on your travels. When this happened, one horse would be slowed so the tow line went slack and the other would step over the rope.

The paths next to canals were once called 'towing paths'. Today, this name is abbreviated to 'towpath'

Despite this inconvenience, horse-drawn barges were particularly valuable as they could haul a much bigger load on land. A horse that is towing a boat from a rope attached to its harness is able to pull up to 40 times more weight than it would be able to on a road. This explains why they were so popular across the UK right up until the 1960s for commercial transport via the country's many canals and waterways.

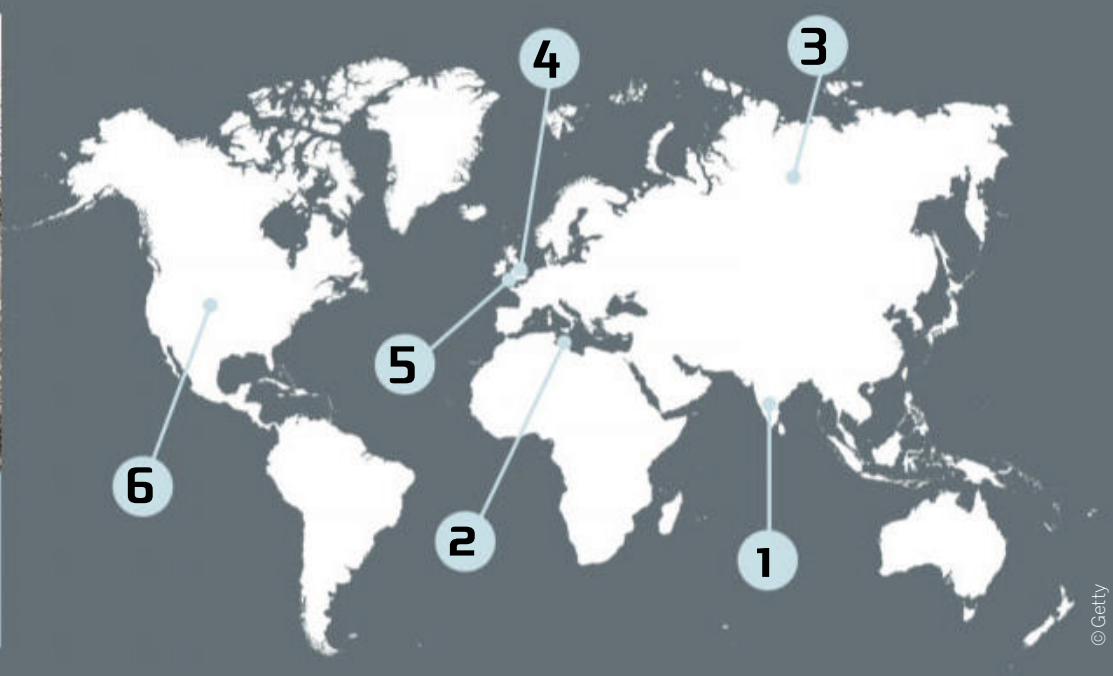
> *"Horse-drawn barges were faster than other alternatives"*

THE LEGACY OF THE HORSE-DRAWN CART

They might look old-fashioned, but horse-powered vehicles are not a relic of the past - sentimental value aside. From the modern-day Amish buggy kitted out with LED lights to the thrilling sport of harness racing, horse-drawn vehicles still have an important place in our world today.

5 Hackney carriage
A four-wheeled six-seating vehicle drawn by two horses, Hackney carriages were once available to hire in London.

6 Kid hack
This van was once used across the United States for transporting children to and from school.



© Getty

How helicopters fly

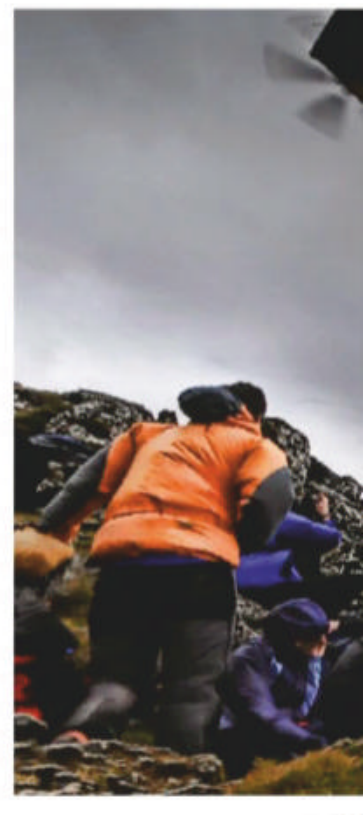
Discover the science behind helicopter flight and what makes them our most inventive flying machine

Helicopters are incredible vehicles. They're able to take off and land just about anywhere, and once in the air they can hover, swivel, yaw, ascend, descend and zoom off in any direction with ease. This amazing airborne control makes them perfectly suited to rescuing people at sea and on land, fighting fires and performing combat manoeuvres. From the ambulance service to the air force to the transport industry, helicopters have become a major asset by reaching the places that no other machine can, and they do it in style.

The concept of a helicopter is over 1,500 years old, and somewhat bizarrely finds its origin as a Chinese toy. Children were instructed to attach feathers to the end of a stick and spin it quickly, which would create enough lift to raise the toy into the air. Leonardo da Vinci would later famously theorise on his own 'aerial screw' during the Italian Renaissance, but it was an 18th-century Russian engineer by the name of Mikhail Lomonosov who would actually assemble a working, spring-powered model of coaxial helicopter blades. About 180 years after him a fellow countryman by the name of Igor Sikorsky would graduate from models of his own to the real thing by patenting and flying in his very own flying machine. Sikorsky's pioneering R-4 would go on to become the world's first mass-produced helicopter.

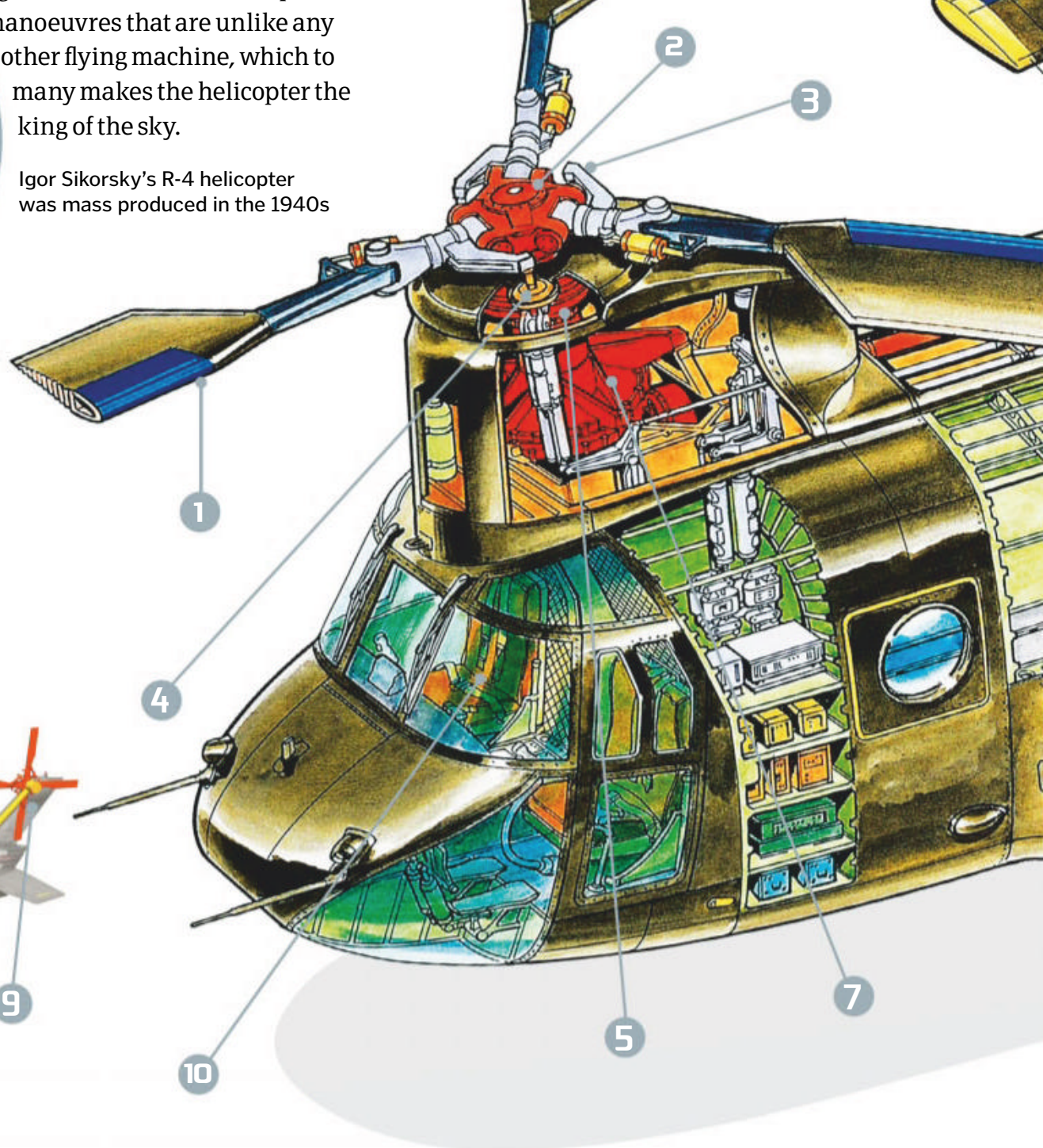
The genius of helicopter design relies on manipulating aerodynamic forces to achieve change in orientation, altitude and speed. By altering the position, relative angles and spin rate of helicopter blades, forces such as lift and torque can be harnessed to push the helicopter in a particular direction. This sophisticated design allows for delicate and precise manoeuvres that are unlike any other flying machine, which to many makes the helicopter the king of the sky.

Igor Sikorsky's R-4 helicopter was mass produced in the 1940s



To the skies

The mechanics that make the helicopter the most versatile machine in the air



1 Main rotor blade
Like an airplane, these blades are shaped as an aerofoil, which narrow to one side and create lift when rapidly rotated.

2 Rotating hinge
Each blade is independently affixed to the rotating mast by a feathering hinge, which allows the blade to swivel.

3 Control rods
Pitch links connect each blade to the swash plate below. When tilted, the raised section of the plate forces the rod to swivel its blade, increasing its pitch.

4 Upper swash plate
The upper plate shares the lower plate's tilt but can spin freely, allowing it to be attached to the control rods.

5 Lower swash plate
Steering controls from the cockpit are relayed to this lower plate, which tilts to influence the upper plate.

6 Changing pitch
Increasing a blade's pitch (how vertical it is) will increase its lift. Increased lift at one location (e.g. the front) will change the helicopter's direction.

The manoeuvrability of helicopters makes them perfectly suited for search and rescue missions

Tandem rotors spin in opposite directions to keep the helicopter flying straight

Tandem rotors

Sometimes less is more, but in the case of cargo helicopters, having double the number of main rotors certainly helps. Enter tandem rotors and one of their famous users, the Chinook. Developed by US Vertol in the late 1950s, the Chinook is used by Britain's RAF today for carrying heavy cargo either in its fuselage or tethered to its underside. Outside of warfare the Chinook has recently been used to re-supply snowbound farmers and to transport aggregate for defence against winter storms.

As well as providing additional lift, the helicopter's second rotor performs an important role that's usually covered by the tail rotor in smaller helicopters. The rotation of the main rotor creates an opposite rotational force on the helicopter's body. Tandem rotor machines use rotors that spin in opposite directions, cancelling out the counter-acting forces. The risk of collision between the opposite blades is also intelligently mitigated by connecting the rotors to the same transmission.

A stabiliser bar can rotate above the main rotor blades to dampen unwanted vibrations

7 Gearbox
Both the main rotor and tail rotor are connected to a gearbox via a driveshaft.

8 Engine
Helicopters can use piston engines like those used in cars but more commonly now use gas turbines akin to jet engines.

9 Tail rotor
As the main rotor rapidly spins the helicopter body will want to spin in the opposite direction. Tail rotors provide torque that negates this force, keeping the body straight.

10 Cockpit
Helicopter pilots must simultaneously control pitch and the throttle to keep the vehicle moving in the right direction.

DISCOVER THE PAST!

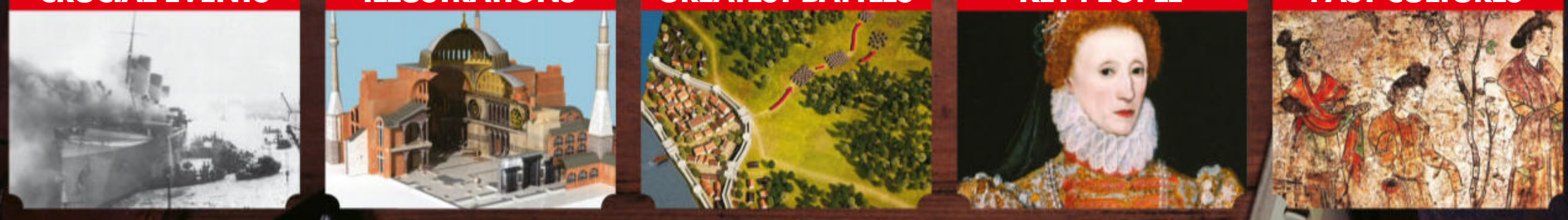
www.historyanswers.co.uk

Available from all good newsagents and supermarkets

ALL ABOUT HISTORY

ON SALE NOW

The Rise Of Sparta • At Queen Victoria's Deathbed • Civil Rights Heroes • Stealing The Mona Lisa



BUY YOUR ISSUE TODAY

Print edition available at www.myfavouritemagazines.co.uk

Digital edition available at www.greatdigitalmags.com

Available on the following platforms

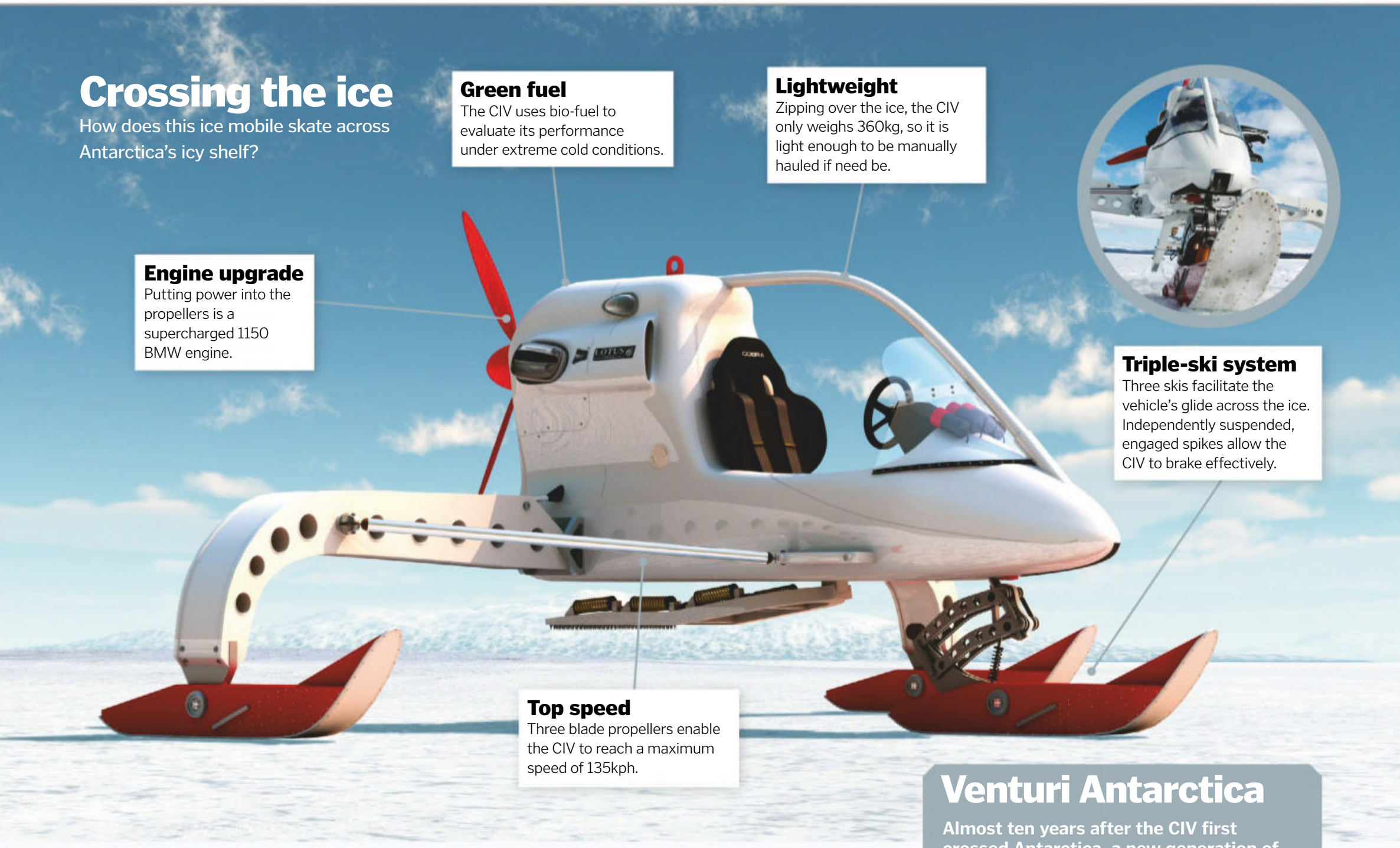
Print Tablet Phone Desktop

facebook.co.uk/AllAboutHistory

twitter.com/AboutHistoryMag

Crossing the ice

How does this ice mobile skate across Antarctica's icy shelf?



Green fuel
The CIV uses bio-fuel to evaluate its performance under extreme cold conditions.

Lightweight
Zipping over the ice, the CIV only weighs 360kg, so it is light enough to be manually hauled if need be.

Engine upgrade
Putting power into the propellers is a supercharged 1150 BMW engine.

Triple-ski system
Three skis facilitate the vehicle's glide across the ice. Independently suspended, engaged spikes allow the CIV to brake effectively.

Top speed
Three blade propellers enable the CIV to reach a maximum speed of 135kph.

Polar-exploring ice mobile

The bio-fuel-powered vehicle that can zip across Antarctica to reach the South Pole

In 2010 a team of researchers and engineers set out to achieve the first there-and-back vehicle crossing, nearly 4,000 kilometres, across Antarctica. Leading the assembly of research transport and a mobile laboratory was the first bio-fuelled machine to reach the South Pole: the Lotus Concept Ice Vehicle (CIV). It was also known as the Winston Wong Bio-Inspired Ice Vehicle in honour of the project's sponsor, Professor Winston Wong.

At its core, the functionality of the CIV is to aid the research conducted on the ice sheet. With built-in radar, the CIV's sensors can penetrate the ice and detect any surprises within it, such as crevasses, before the rest of the team encounter them. Mounted on three skis and thrust across the ice by way of three propellers, the CIV is able to navigate the unpredictable terrain of the Antarctic surface. One of the predominant reasons for the creation of the vehicle was to monitor and research the chilling effects of the environment on the CIV's bio-fuel reserves. As it's one of the regions of the planet most affected by pollution, green or zero-emission solutions for human activity at the Antarctic are paramount.

The Lotus Concept Ice Vehicle is 4.5 metres wide and 4.5 metres long

Venturi Antarctica

Almost ten years after the CIV first crossed Antarctica, a new generation of vehicles have been designed to withstand the continent's harsh conditions, most recently the Venturi Antarctica.

With the final model unveiled at the Prince's Palace in Monaco in late 2018, the two-ton vehicle is set to visit the ice shelf in 2019. The Venturi Antarctica is the first electrically powered exploration vehicle, equipped with an 80-horsepower motor system that can propel it at speeds of around 20 kilometres per hour. In order to combat the harsh conditions on the continent, the Venturi Antarctica travels on wheel-mounted caterpillar tracks and can withstand temperatures as low as minus 50 degree Celsius.

With a range of 45 kilometres, three passengers and luggage can zip to research areas previously difficult to access. The Antarctica will complete a test run in Canada in March 2019.

Venturi's focus on Antarctica was inspired by Prince Albert II of Monaco's visit to the region

HOW CLONING ANIMALS WORKS

Words by **Charlie Evans**

When Dolly the cloned sheep was born so was a new era of biological research

She was born into the world like any other sheep – tiny, fluffy and bleating. But Dolly wasn't the same as any other sheep. Or rather, her uniqueness was that she was like just one other sheep. In fact, she was identical to one other sheep. Dolly was a clone.

Clones are organisms, or cells, that are genetically identical to their parent, and they have existed in nature for millions of years. Single-celled organisms and plants can produce genetically identical offspring and natural clones, for example identical twins, occur in humans and other mammals. These natural clones have almost identical DNA. However, animal cloning has been experimented with for over 100 years, starting with more basic animals like salamanders and working up to complex mammals like sheep and cows.

Two cloned beagles, Magic and Stem, were born at the National Seoul University in January 2009 in Seoul, South Korea

DOUBLE TROUBLE: CLONING METHODS

There are two main methods of cloning animals: somatic cell nuclear transfer (SCNT) and embryo splitting. It was the SCNT method that was used to produce Dolly the sheep. Both methods are forms of 'reproductive cloning', a type of artifical cloning of which gene cloning and therapeutic cloning are also a part of.

REPRODUCTIVE CLONING

SCNT cloning starts with finding a suitable nucleus donor. These can be obtained directly from the animal or they can be grown in a laboratory. They are usually skin cells, which have a relatively long lifespan and can tolerate being frozen. The other cell that needs to be obtained for the cloning procedure is an egg cell. The egg cell is enucleated – a process that involves sucking out the nucleus by using a tiny needle. When the cell has been enucleated there is no DNA left behind, but it remains filled with cytoplasm. The nucleus donor cell is enucleated in the same way, but instead of being discarded the lone nucleus is injected into the egg cell. An electric shock is applied, which triggers it to start dividing. If everything goes well the embryo is implanted into a surrogate. The cells divide normally, and a few months later a healthy clone is born. So far, there is no evidence that the process is at all detrimental to the clone. Dolly was able to reproduce and had healthy offspring, which suggests even her fertility was not impacted by the way she came into life.

"Animal cloning has been experimented with for over 100 years, starting with more basic animals like salamanders"

THERAPEUTIC CLONING

Therapeutic cloning uses the same methods, right up until the point of electric shock. The donor cell, however, belongs to a cell from a patient in need of stem cells. After the fused cells have divided several times it becomes a pre-embryo ball of cells known as a blastocyst. A

Achievements in cloning history

The breakthrough moments in scientific history that advanced the field of cloning

1938
Hans Spemann proposes a "fantastical experiment" to transfer one cell's nucleus into an egg without a nucleus, the basic method that would eventually be used in cloning.

1952
Robert Briggs and Thomas King successfully transfer the nucleus from an early tadpole embryo into an enucleated frog egg.

1984
Steen Willadsen clones a sheep from an embryonic cell in a technique known as nuclear transfer.

1996
Dolly the sheep – the first mammal to be cloned from an adult body cell – is born.

2001
Two animals – a mouflon sheep and a gaur (Indian bison) – are cloned as part of an effort to save these species.

2003
Researchers successfully clone the first extinct animal, a Spanish mountain goat called the bucardo, but the clone died minutes after it was born.

2013
Human embryos are cloned for the first time to produce embryonic stem cells with the hope they may go on to treat diseases.

Dolly is possibly the world's most famous clone

The life of Dolly the sheep

Dolly was born on 5 July 1996 at The Roslin Institute in Scotland. Her birth was a result of an experiment to develop genetically modified livestock. She had three mothers: a Finn-Dorset provided the DNA, a Scottish Blackface provided the egg and a third, a Scottish Blackface, was impregnated with the embryo. 148 days later, the surrogate ewe gave birth to Dolly. She was the sole surviving adult from 277 cloning attempts.

Dolly went on to have six healthy lambs, all conceived naturally. She died at the age of six from a disease unrelated to her being a clone, but her life encouraged scientists to continue experiments with other animals. Since then pigs, cats, cows, horses and even camels have been successfully cloned.

The Seoul National University and RNL Bio Company offers clients a service to clone their dead pets

blastocyst has an outer and inner layer, and within the inner layer are the prized stem cells. While most cells are specialised to a specific job (i.e. neuron, muscle cell etc.) stem cells have the potential to develop into any type of cell. The harvested stem cells are infused into a patient and, under the right conditions, start functioning where needed.

EMBRYO SPLITTING

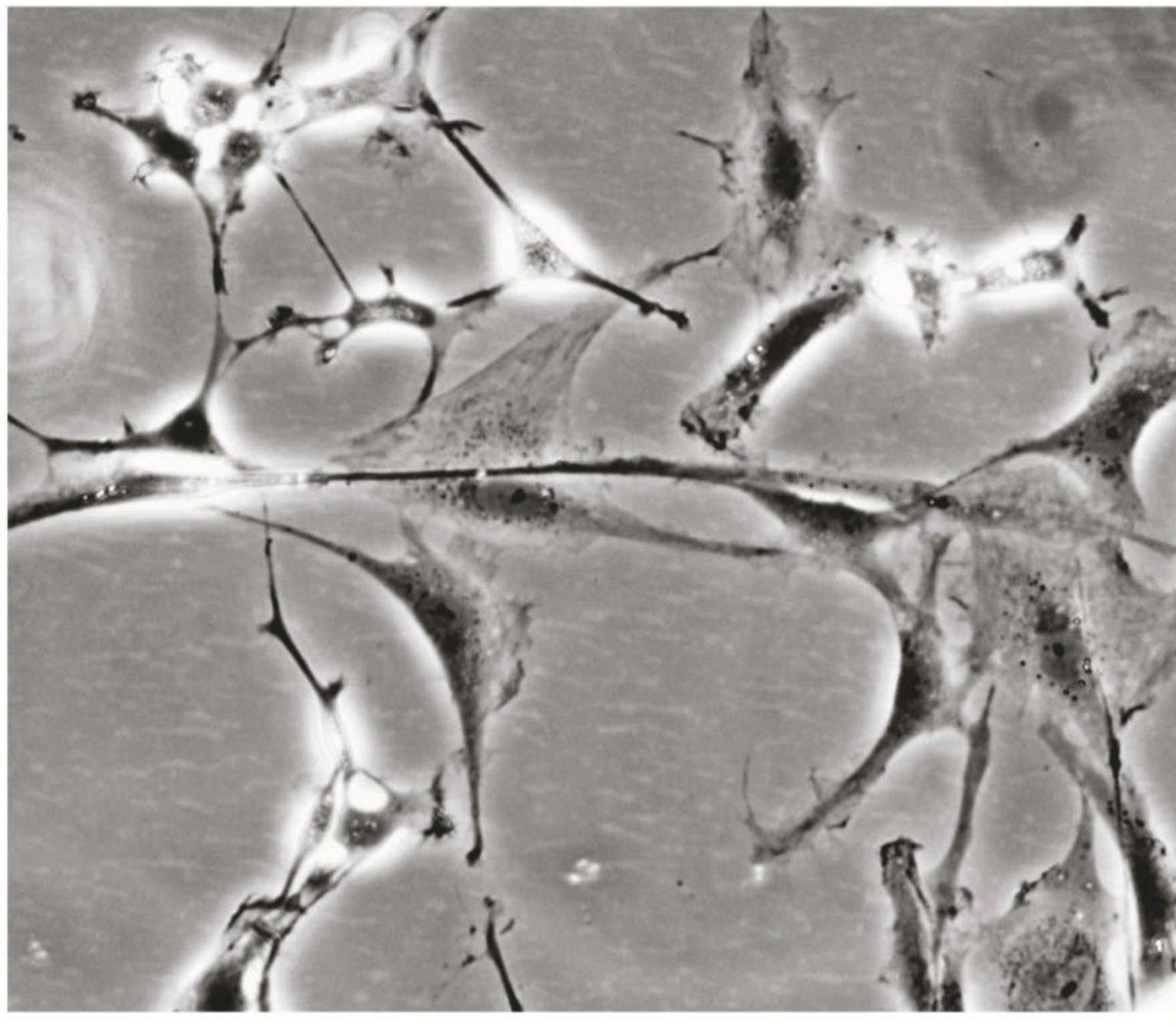
The simplest form of artificial cloning, this method begins with the formation of a zygote. This zygote divides and eventually the embryonic cells can be separated. Each separated cell continues growing and can be implanted into a surrogate. The implanted cells are identical as they were originally formed from the same embryo. This process is similar to that of the development in identical twins but has a limited potential.

CAN WE CLONE HUMANS?

Undoubtedly, cloning is a powerful biological technology. Scientists have been able to use the technique to breed endangered species and resurrect extinct animals. There has even been talk of bringing back the woolly mammoth after the discovery of preserved soft-tissue remains of these prehistoric giants. Yet, while laboratories are researching and developing therapeutic cloning using human tissue, there have been no actual human clones created to date. This is partly due to the ethical problem of bringing cloned individuals into existence without fully knowing if the method is safe or what the impact might be on the cloned human's life. Other concerns include the fact that reproductive cloning could be prone to wide-scale abuse, such as cloned humans being used for organ and tissue harvesting.

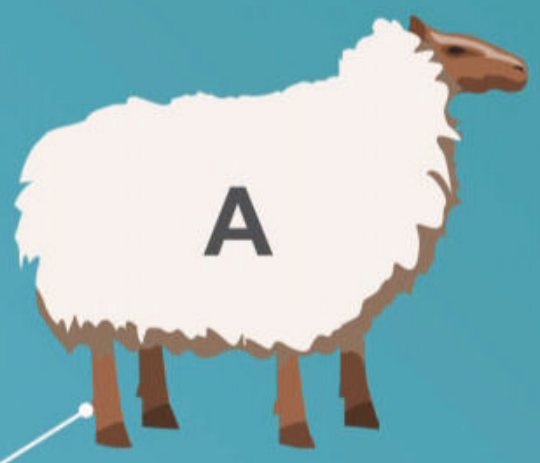
WHAT'S THE POINT?

Cloning is expensive, time-consuming and has a very low success rate. However, developing these methods has been vital to our understanding of human developmental biology and has provided new treatment options in medicine. It is hoped that soon patients with an organ disease or failure will no longer have to risk their body rejecting their new transplant. Instead, they will be able to replace the organ with one that is genetically identical but without the wear and tear. It won't be long until we see scientists growing new livers for patients with liver disease, new hearts for transplants and even new brain neurons for people suffering from brain injuries – all perfectly genetically identical to the patient.

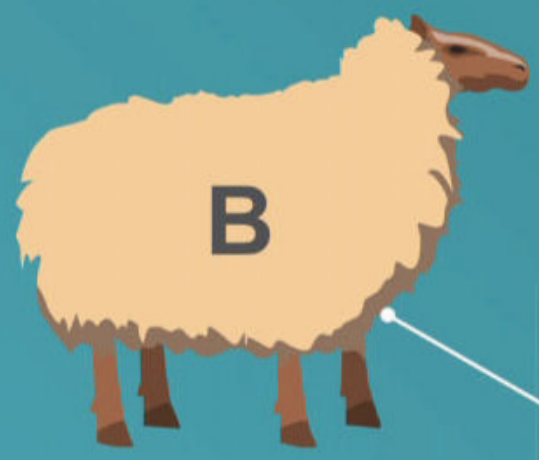


How does cloning work?

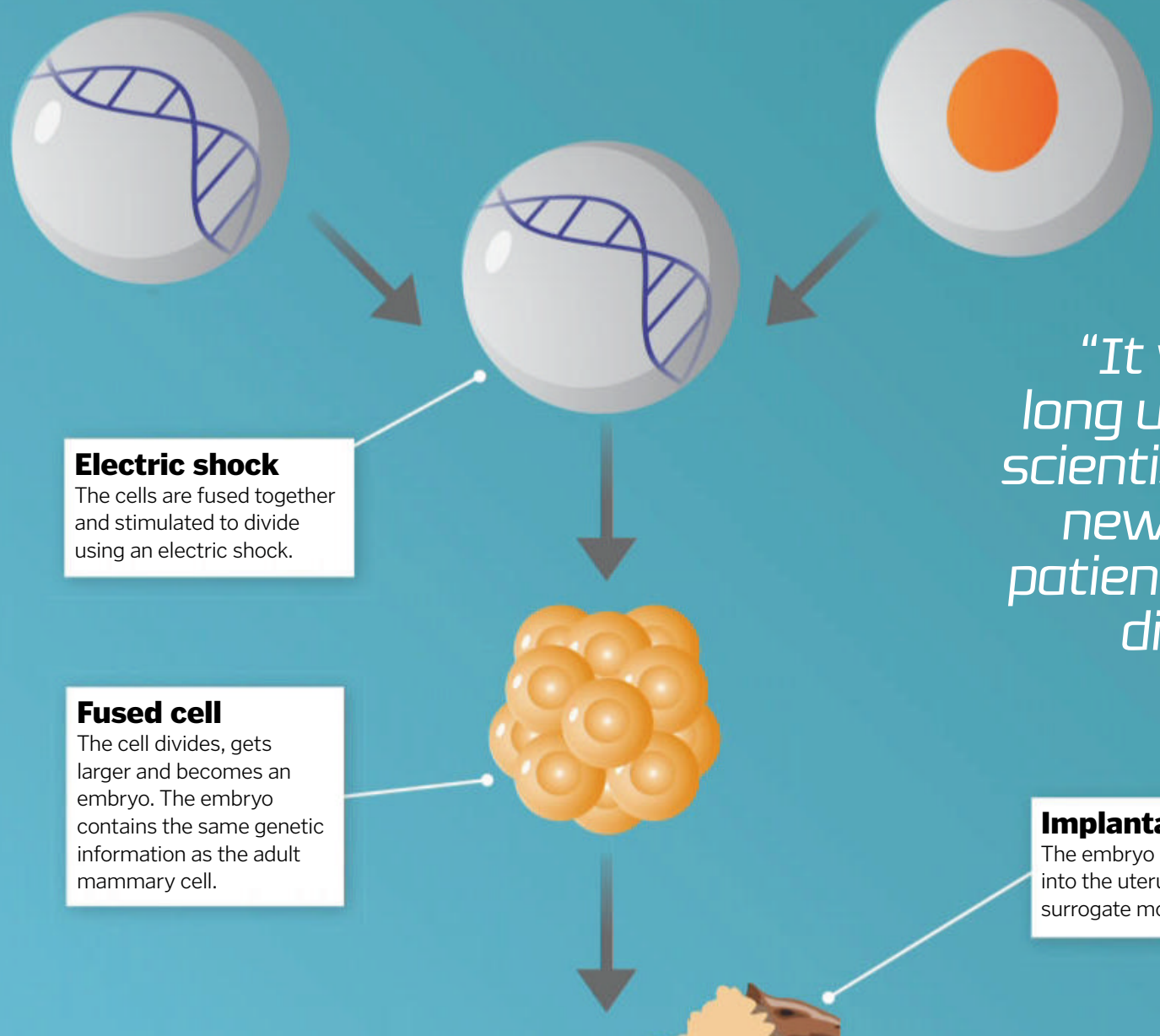
The incredible process behind creating genetically identical organisms



Donor mammary cells
A donor cell has its nucleus removed and the rest of the cell is discarded.



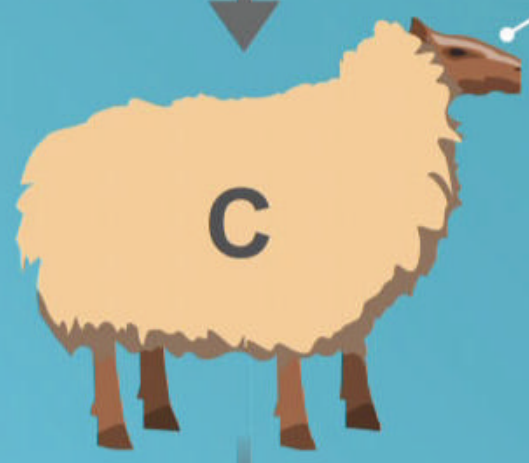
Adult donor cells
An enucleated egg cell from another donor is injected with the extracted nucleus.



Electric shock
The cells are fused together and stimulated to divide using an electric shock.

Fused cell
The cell divides, gets larger and becomes an embryo. The embryo contains the same genetic information as the adult mammary cell.

Implantation
The embryo is inserted into the uterus of a surrogate mother.



Clone is born
The embryo develops normally and is born.

Colonies of neural stem cells are capable of differentiating into any cell of the nervous system

"It won't be long until we see scientists growing new livers for patients with liver disease"

A researcher at the laboratory where Dr. Ian Wilmut discovered how to clone a sheep

What makes muscles strong?

With every simple move we make our muscle cells are working overtime

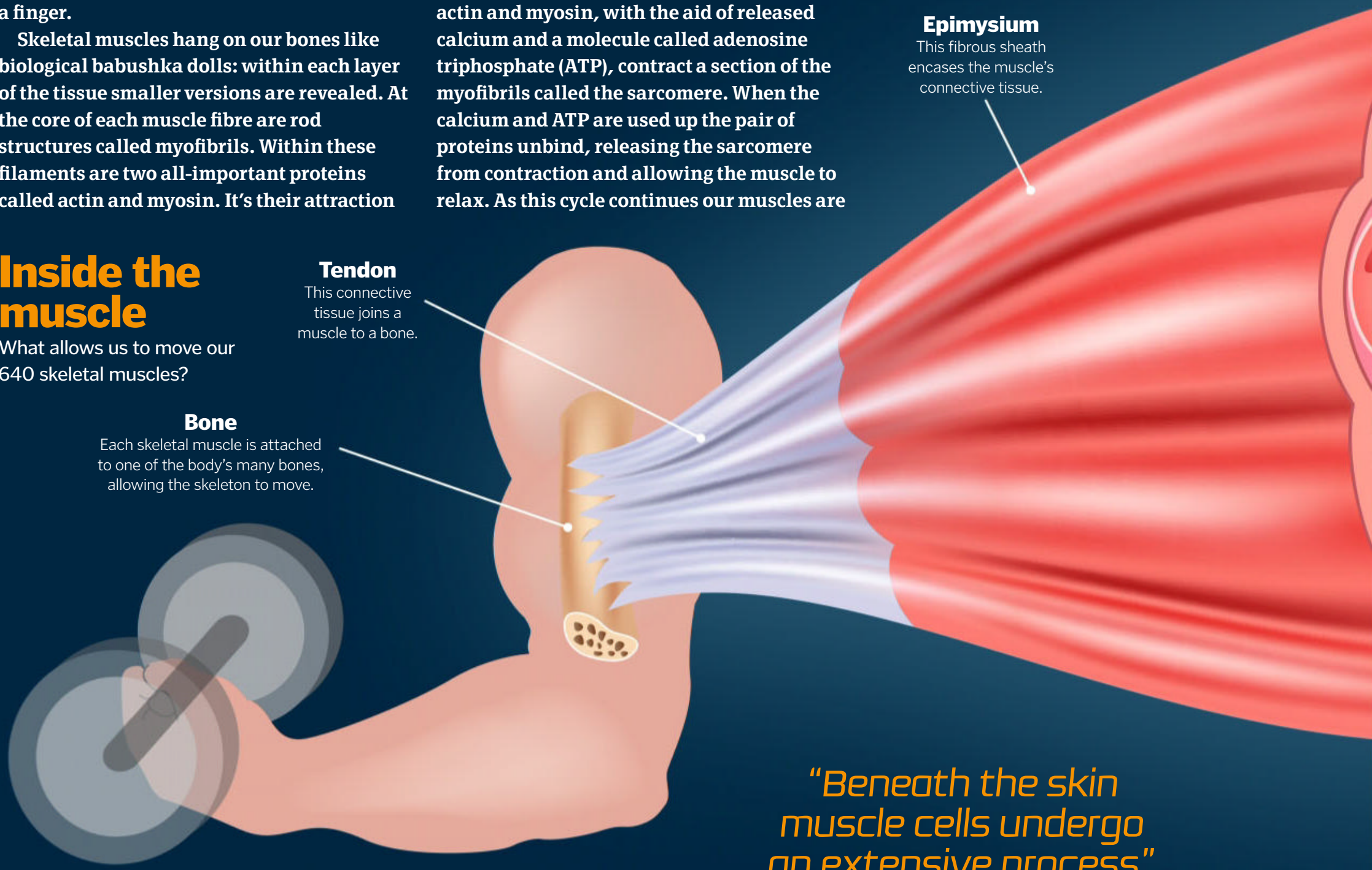
Moving our limbs seems like a relatively simple task. Whether it's picking up a cup of tea or taking a walk, the process of movement appears instant and without much thought. However, beneath the skin our skeletal muscle cells are undergoing an extensive process to simply lift a finger.

Skeletal muscles hang on our bones like biological babushka dolls: within each layer of the tissue smaller versions are revealed. At the core of each muscle fibre are rod structures called myofibrils. Within these filaments are two all-important proteins called actin and myosin. It's their attraction to one another that is responsible for the contracting and relaxing of muscles. However, it's only after a chain reaction of molecules is released throughout the tissue that the pair are allowed to come to together.

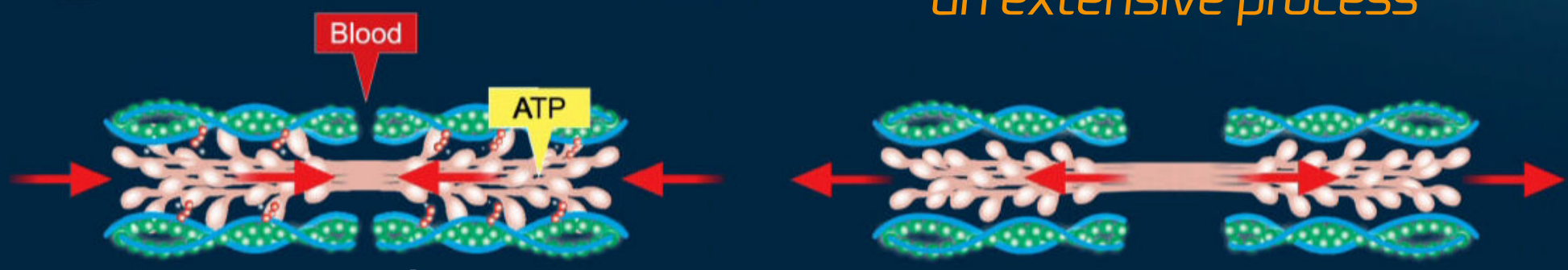
These proteins interact in what is known as the sliding filament model or theory. The actin and myosin, with the aid of released calcium and a molecule called adenosine triphosphate (ATP), contract a section of the myofibrils called the sarcomere. When the calcium and ATP are used up the pair of proteins unbind, releasing the sarcomere from contraction and allowing the muscle to relax. As this cycle continues our muscles are able to animate our bodies. The collective tissue pulls the muscle together, then connective tissue called tendons, which grip the surrounding bone, follow suit. When the muscle contracts the two attached bones are pulled together and thus produce movement.

Inside the muscle

What allows us to move our 640 skeletal muscles?



"Beneath the skin muscle cells undergo an extensive process"



Contraction

Calcium released into the myofibril binds with the tropomyosin and troponin, allowing myosin to bind. ATP is also delivered from neighbouring mitochondria, which binds to the myosin head to create a shape compatible with the actin. When the two are bound the filament becomes shorter and therefore contracts.

Relaxation

Once the ATP and calcium are used up the actin and myosin cannot interact, resulting in the actin-myosin bond being broken. This causes the muscle to relax and therefore lengthens.

DID YOU KNOW? *The smallest muscle in the body is the stapedius, located inside the ear, and measures just over 1mm*

Muscles make up around 40 per cent of a human's body weight

The endomysium holds within it bundles of myofibril fibres for muscle contraction

Blood vessels
These vessels deliver oxygen through red blood cells to the muscle cells.

Perimysium
This is more connective tissue that separates the bundles of muscle fibres known as fascicles.

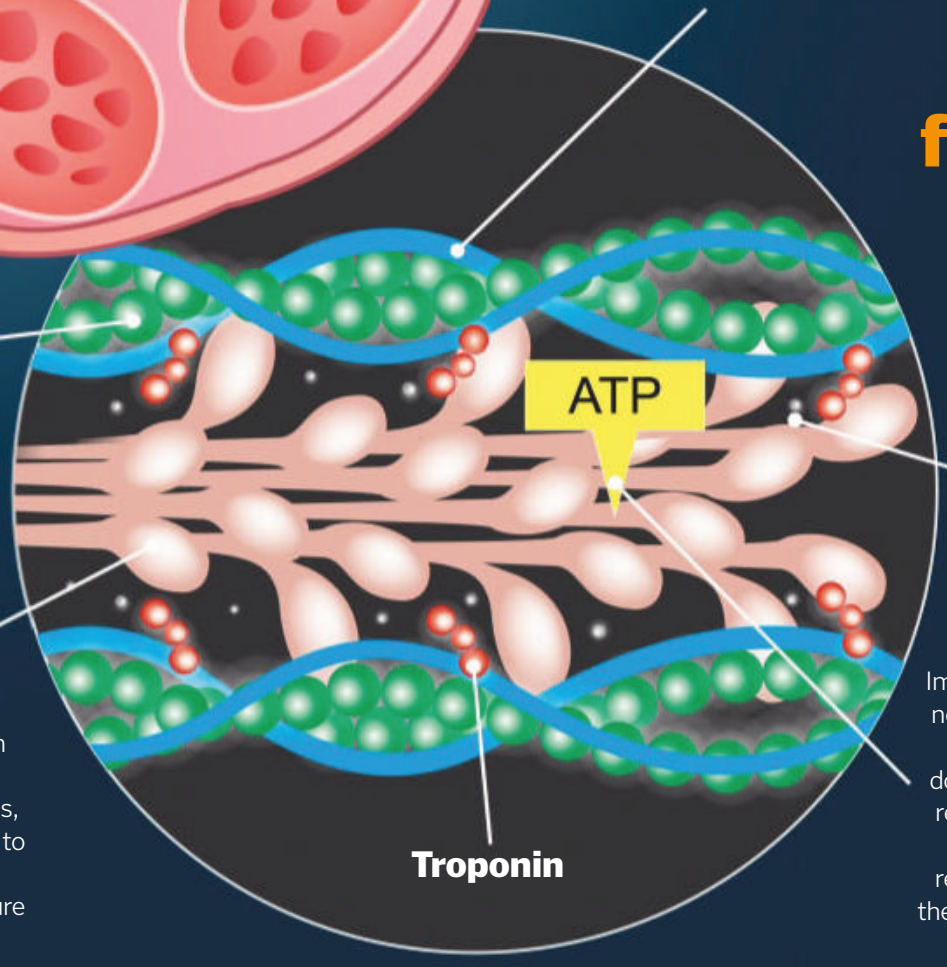
Myofibril
These threads of contractile filaments house the proteins needed for muscle contraction.

Nuclei
As the most important organelle in a cell, the nuclei holds the genetic information that is vital to a cell's formation.

Sarcolemma
This is the plasma membrane of the muscle cells and has cavities to allow chemicals such as calcium into the cell for contraction.

Sliding filament model

Discover the mechanics behind our muscles



Actin
This beadlike protein is twisted together to form a filament.

Myosin
A thick protein filament with protuding heads, this is designed to bind with the beadlike structure of the actin.

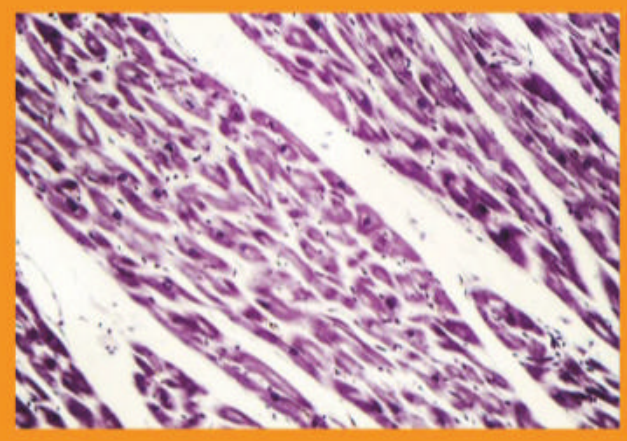
Impulse
Impulses sent via motor neurons travel down to the myofibril and by doing so trigger a chain reaction of events, the final one being the release of calcium and the delivery of ATP within the myofibril.

Creating a heartbeat

The heart is arguably one of the most important muscles in our body. Typically beating between 60 and 100 times a minute in an adult, it continuously contracts and relaxes to circulate blood around the body, without ever tiring. However, the structure of the cardiac muscle is unique to this vital organ.

Though similar to skeletal muscle cells, cardiac cells are more extensively branched and connected via intercalated discs. These discs allow the cardiac muscle cells to move like a wave rather than in a linear motion as skeletal muscle cells do. This wave motion is what allows the heart to become a pump.

Though there is a need for electrical impulses to cause contraction, heartbeats are controlled by the autonomic nervous system (ANS), whereby electrical signals activate muscle cells without conscious thought.



Cardiac cells contract to enable the heart to pump. The average heart beats 100,000 times a day

DISCOVER THE UNIVERSE

www.spaceanswers.com

All About Space

Available from all good newsagents and supermarkets

ON SALE NOW

Asteroid Bennu > Our Sun is getting hotter > Phantom worlds > Ultima Thule

BUY YOUR ISSUE TODAY

Print edition available at **www.myfavouritemagazines.co.uk**

Digital edition available at **www.greatdigitalmags.com**

Available on the following platforms

Print Tablet Phone Desktop

facebook.com/AllAboutSpaceMagazine twitter.com/spaceanswers

Why do we have body hair?

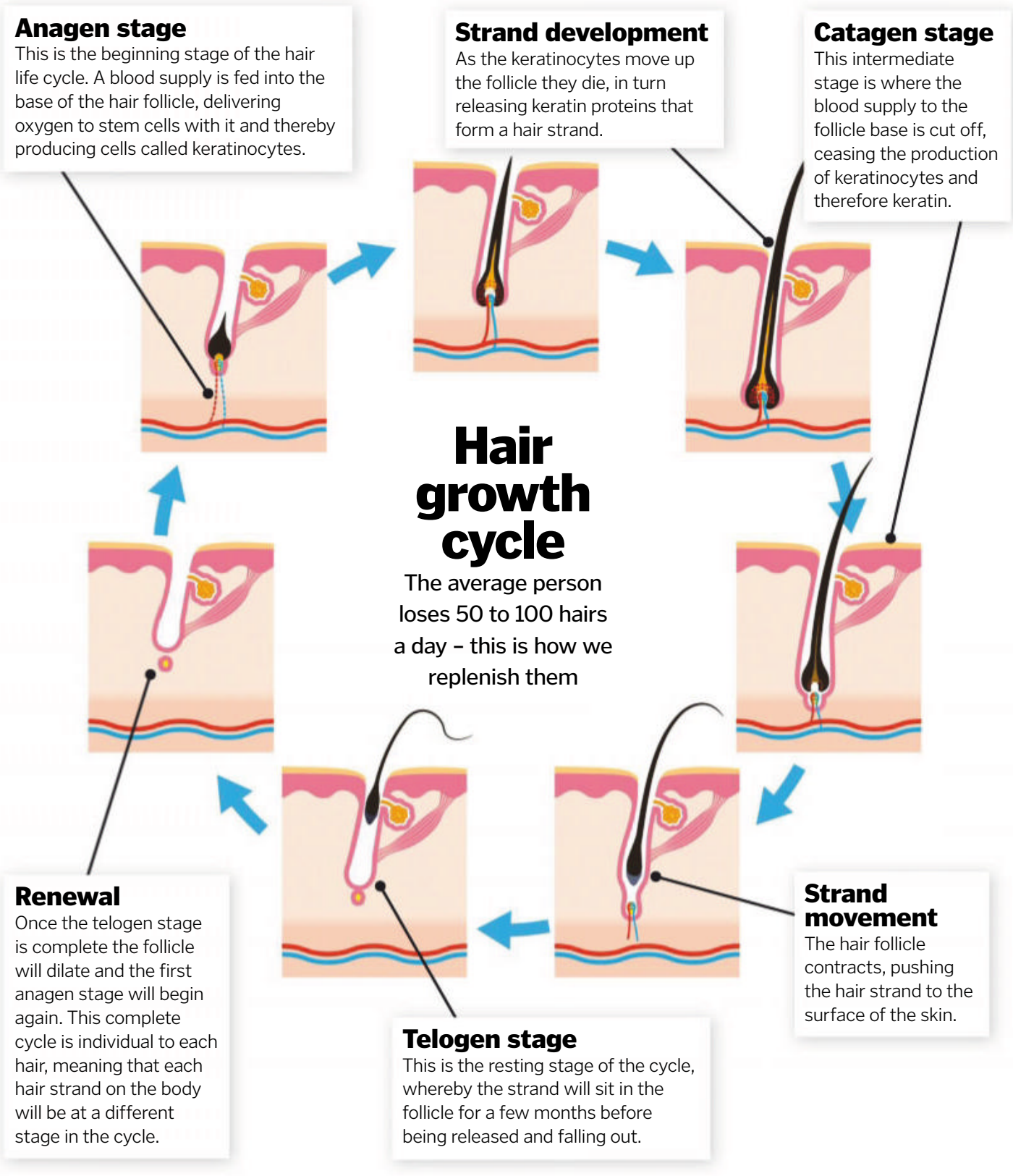
Some have more of it than others, but what is the purpose of our hairy patches?

Body hair is not there by chance – it has played a vital role in our species' survival. As our prehistoric ancestors ditched swinging from the treetops to stand on two legs and pace the savannah plains, thick fur posed a problem for heat regulation and so the majority was lost, with the exception of a few patches, most notably on our heads. Evolutionary shedding of thick body hair also removed the threat of parasitic hitchhikers.

Today, as two-legged 'naked apes', the most exposed part of the human body to the Sun's ultraviolet rays is the head, which retained hair for protection. We have also evolved the ability to sweat to cool our bodies down in the heat from glands called apocrine sweat glands. These glands not only release a cooling fluid but pheromones too. Patches of our body hair are conveniently located where these glands are found to trap the sweat and hold on to the pheromones in order to attract a mate.

However, though we may appear to be a bald version of our primate cousins, humans and other apes still share the same amount of hair follicles, which is on average around 5 million. Humans simply no longer grow thick coats.

Men tend to have higher levels of testosterone, which results in increased body-hair growth compared to women



Anagen stage
This is the beginning stage of the hair life cycle. A blood supply is fed into the base of the hair follicle, delivering oxygen to stem cells with it and thereby producing cells called keratinocytes.

Strand development
As the keratinocytes move up the follicle they die, in turn releasing keratin proteins that form a hair strand.

Catagen stage
This intermediate stage is where the blood supply to the follicle base is cut off, ceasing the production of keratinocytes and therefore keratin.

Hair growth cycle
The average person loses 50 to 100 hairs a day – this is how we replenish them

Renewal
Once the telogen stage is complete the follicle will dilate and the first anagen stage will begin again. This complete cycle is individual to each hair, meaning that each hair strand on the body will be at a different stage in the cycle.

Telogen stage
This is the resting stage of the cycle, whereby the strand will sit in the follicle for a few months before being released and falling out.

Strand movement
The hair follicle contracts, pushing the hair strand to the surface of the skin.

Werewolf syndrome

Typically, hair will continue to grow to a set length depending on its location on the body. The hair on the head can continue to grow for a metre or so, whereas underarm hair will cease new growth after a few centimetres. However, there is a rare genetic condition known as congenital generalised hypertrichosis, or 'werewolf syndrome' as it is commonly known, whereby excessive hair growth appears in patches or covers the body when compared to others of a similar age, gender and race. This is believed to the result of an extra collection of genes on the X chromosomes. Though different collections have been recorded in different patients, their location on the chromosome remains the same. This has led researchers to believe that this extra collection of genes activates other hair-growth genes.

Supatra 'Nat' Sasuphan from Thailand won the Guinness World Record for hairiest girl in 2010

INSIDE A MONEY FACTORY

From workshop to wallets, how does the world's money reach our back pockets?

Words by **Scott Dutfield**

DID YOU KNOW? *In the first release of the UK's polymer £5, 440 million notes were printed with a value of £2.2 billion*

As online banking and contactless cards continue to grow as our preferred method of payment, physical money may one day be a thing of the past. However, with more than 3.6 billion Bank of England notes in circulation, making money is still a thriving business, one that's been around for thousands of years. Civilisation began this economic journey through bartering (the trading of items deemed of equal value) around 9000 BCE. It wasn't until around 600 BCE that Lydia, an ancient civilisation now part of Turkey, introduced the world's first coins as currency, made from a naturally occurring mixture of gold and silver called electrum.

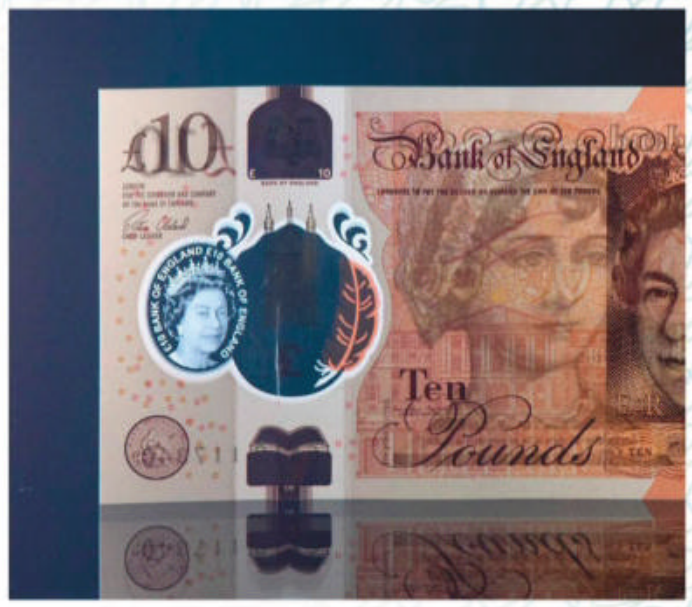
As the concept of currency spread across the globe coins gave way to paper notes. Though sometimes referred to as 'paper' currency, traditional banknotes are not made from pulped wood but in fact cotton, or in the case of the US dollar, a blend of cotton and linen. Cotton bales are 'plucked' by heavy machinery before being filtered for imperfections and bleached. Fibres are then pressed to remove water and feed through rollers to form sheets. Watermarks and security features are placed on the sheets before final designs are printed and the notes are cut.

PAYING WITH PLASTIC

In recent years 'paper' money has been replaced by a thin, flexible plastic polymer material. These polymer notes are more resistant to dirt and moisture and have a stronger composition than their paper counterparts. Made from durable plastic compounds such as polyethylene terephthalate (PET) or biaxially oriented polypropylene (BOPP), the plastic notes start out as small pellets. These pellets are melted, and then stretched into an enormous bubble to cool that can stretch up to five storeys tall. Once the base of the bubble has cooled sufficiently it is rolled out into a sheet. This then passes through an infrared gauge to check the thickness. Once they have been quality checked the sheets of plastic are rolled up, packaged and sent out for the final banknote designs to be added.

In the first half of 2018, about 223,000 counterfeit banknotes were discovered, so money makers have had to develop different ways to ensure the safety of their notes. Each note, depending on the country of origin, contains several security features that distinguish the real notes from the fakes. Polymer notes are much tougher to make forgeries of, and the addition of transparent windows, foils, holograms and ultraviolet treatments are used to verify their authenticity. Security measures are even applied to the artwork, with hidden designs, textures and raised print known as intaglio printing often used to foil would-be forgers.

Coin currency was first introduced in Lydia, modern-day Turkey, in around 600 BCE



The polymer £10 note entered circulation in September 2017. It will be joined by a plastic £20 note in 2020

Brunei 1996

Papua New Guinea 1991

Romania 1999

Australia 1988

Vietnam 2003

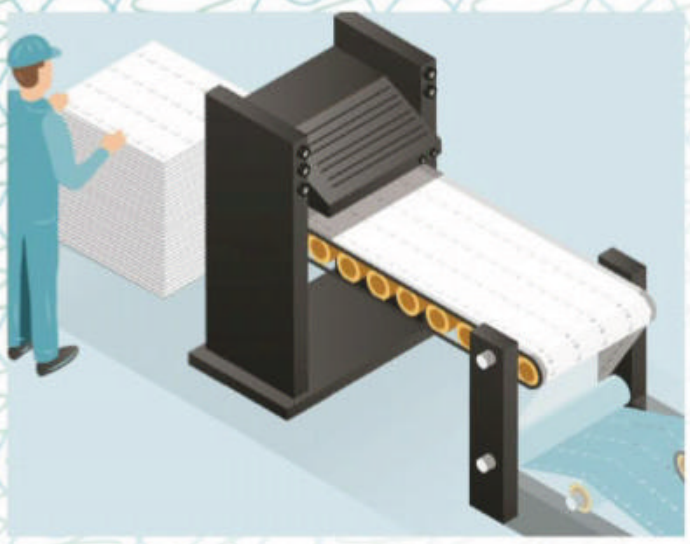
New Zealand 1999

Show me the polymer

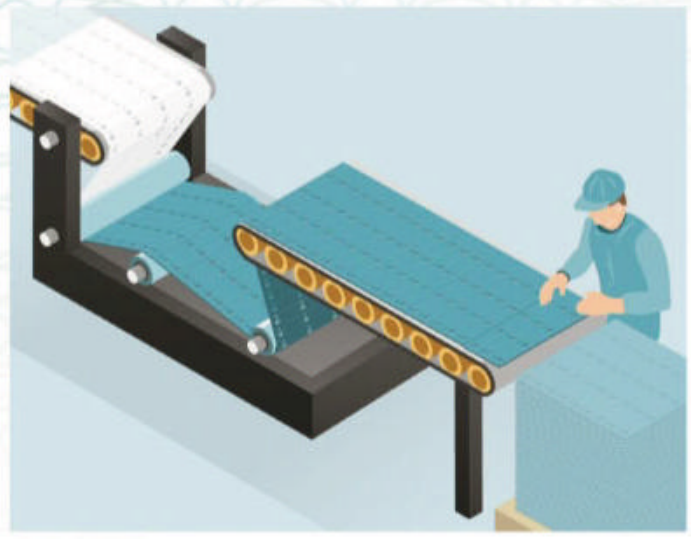
Ditching paper payment, these pioneering countries put polymer on the map

Putting a price on plastic

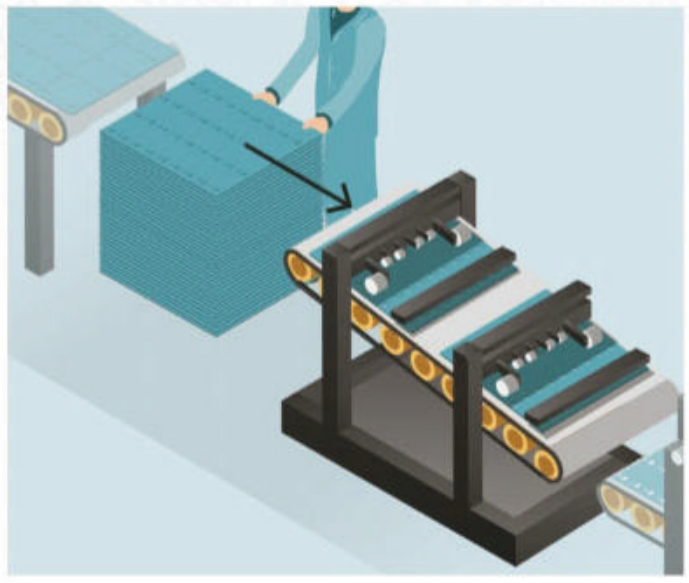
Step-by-step, how simple plastic is transformed into a valuable banknote



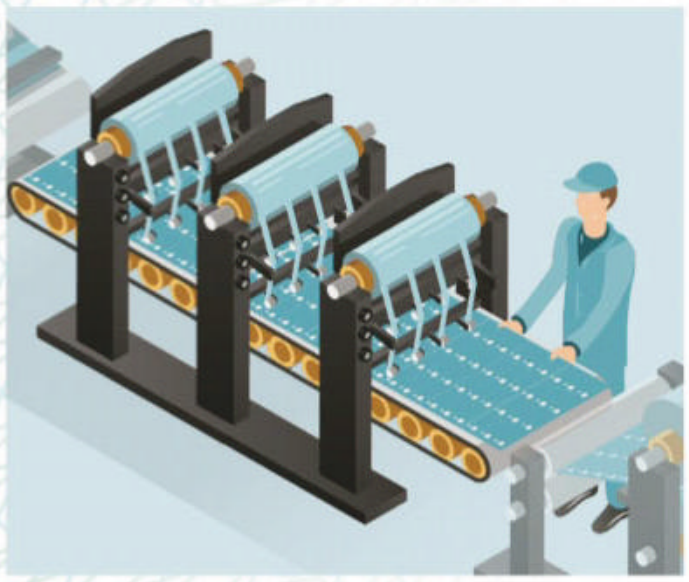
1 Blank sheets
Imported sheets of polymer substrate, housing the transparent window, are loaded into the printing process.



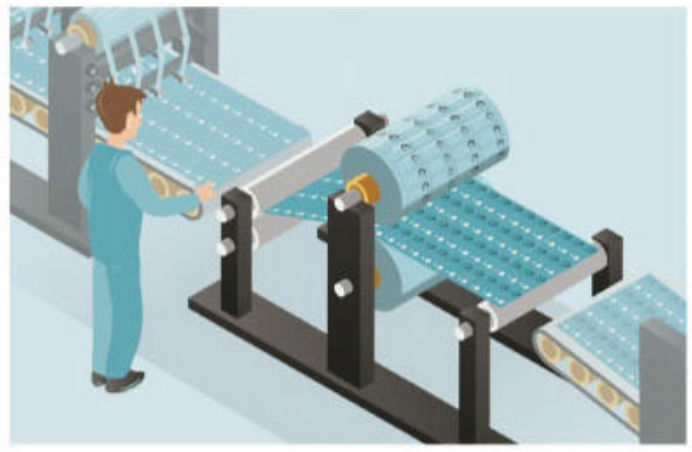
2 Base print
Computer-generated background designs are then printed onto both sides of the polymer sheets.



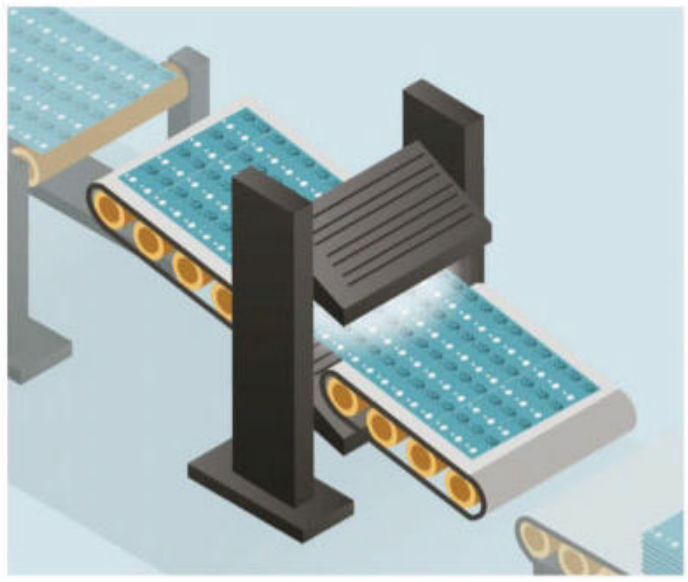
3 One at a time
Printed sheets are then fed individually into a foiling machine.



4 Applying foil
From a tape, strips of foil are applied to the uncut polymer sheets.

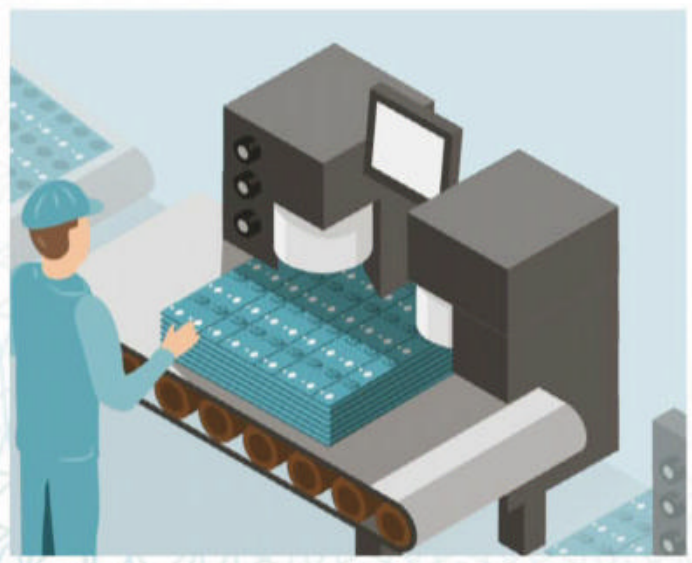


5 Security features
Portraits of county's iconic figureheads are then added to either side, such as Queen Elizabeth II. The printing for these portraits is typically intaglio or textured for security purposes, making them much harder to copy.

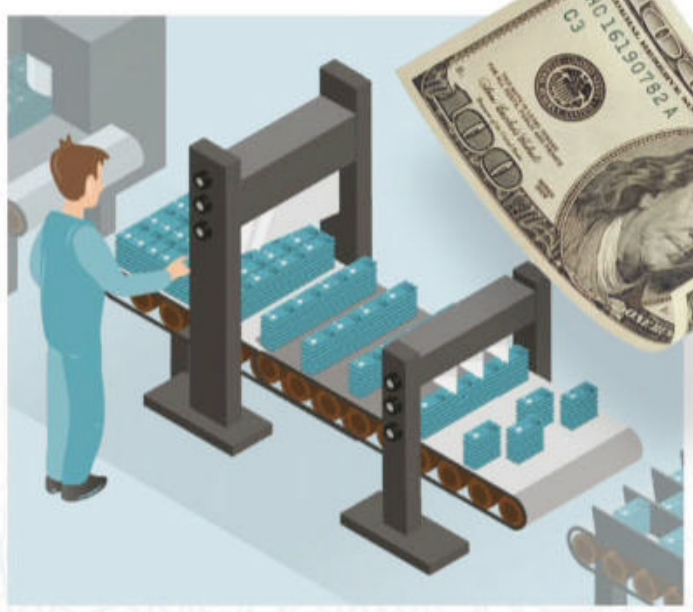


6 UV treatment
Sheets are then treated with ultraviolet light as a security measure.

Coin face designs are transferred onto stamp dies at the hand of a precise computer-controlled engraving machine



7 Making the grade
Quality control checks are carried out and the polymer sheets are counted.



8 Cutting to size
In order to separate the individual notes, stacks of sheets are put through a guillotine.

"See-through windows, foils, holograms and UV light are used"

Several security measures are taken to prevent fraudulent note production, including unique holograms

9 Final checks
Notes are then stacked, checked, tested and counted again.

10 Off to the banks
Finally, notes are packaged in bundles and stored in secure cages ready for transport.

Creating coins

How the mint turns metal into coin currency

Raw materials
Rolled sheets of metal alloy of a precise thickness are fed into a blanking press.

'Pickling' in acid
To remove any blemishes discs are added to a pickling bath, whereby ball bearings, sulphuric acid and the discs are mixed together to remove any imperfections.

Stamping dies
Blanks are poured into the stamping press, where each of them is struck by a die/stamp that imprints the coins with their final design.

Coin punching
Blank discs are punched out to their size and shape at a rate of up to 10,000 per minute.

Softening the metal
These future coins are then passed through an annealing furnace to soften the metal in preparation for stamping.

Finished product
Freshly formed coins are checked and counted before being packaged and dispatched.

Extreme polar survival

Discover the gear that keeps people alive in the most unforgiving regions of Earth

Researchers employ advanced tech for both their science and survival when at the poles

Humans are, by design, warm-climate animals. Our skin lacks fur and we can't easily store a thick layer of insulating fat. Even so, we've now spread all around the globe, and an increasing number of people are finding reasons to venture into the most extreme latitudes found at our planet's poles. Due to climate change previously solid ice sheets have thawed and opened the Northern Sea Route, making it accessible to traders, who've joined fishing vessels, oil rig workers and cruise ships in the colder waters.

On land, militaries with territory in the Arctic Circle have made permanent bases on the inhospitable terrain, and in the Antarctic region in the south researchers and adventurers continue to wrestle with nature, particularly during the brutal Antarctic winter. Yet we humans not only endure but even surmount nature's formidable challenges thanks to our ever-developing technology.

Some of the more amazing feats of engineering and design were on display during explorer Sir Ranulph Fiennes expedition to traverse Antarctica during winter. Although halted prematurely by mammoth crevasses, the expedition's team used the most advanced survival technology of the time to penetrate the frozen continent. Gloves and soles containing heating elements were woven into a power loom that ran throughout the suits, providing heat for the skiers' most vulnerable extremities. Their masks also used expired air to warm incoming fresh air, reducing the temperature gradient in their lungs. Beside them were two bespoke variants of the Caterpillar D6N tractor, equipped with a boiler and spare electrical heating element to allow the vehicle to operate at -70 degrees Celsius. This dragged their shelter and supplies.

Adventurers are not alone in utilising sophisticated technology, and whether it's soldiers equipped to march through the brutal winter months or fishermen shielding themselves against the elements as they await rescue, humans are more capable of surviving the extreme cold of the poles than they have ever been.

5 FACTS ABOUT THE TECHNOLOGY AND DANGERS OF POLAR SURVIVAL

1 The human hypothermia recovery record
Doctors in Norway successfully resuscitated a patient with hypothermia so severe that their core body temperature had dropped to 13.7 degrees Celsius. Despite undergoing cardiac arrest the patient was saved.

2 Space technology on Earth
Cold survivalists have benefitted from NASA's space exploration, namely in the form of insulated materials. These include commonly used insulating 'space blankets' and temperature-resistant tapes.

3 Zero Celsius kills quickly
If you were to fall into a body of water at around 0 degrees Celsius unprotected your body would likely enter shock in less than two minutes and lose consciousness in less than 15 minutes.

4 Clothes with built-in warning sensors
Sintef's ColdWear Project has developed sensors that can be integrated into clothing. These will be capable of recording inputs such as humidity, wind, temperature and heat transport and can operate in extreme temperatures.

5 They treat hypothermia from the inside
Patients with body temperatures between 27 and 32 degrees Celsius can be treated with warm fluids directly into internal organs through tubing and IVs, which warm the body more effectively than external insulation.

Militaries with interests in the Arctic Circle are equipped with specialised gear for the extreme cold

Arctic military gear

Russia has multiple military bases on its northern frontier, which encroaches into the Arctic Circle. To ensure the country's troops are ready to defend this expansive border if the need arises, the military conducts drills at the North Pole to harden their soldiers against the cold and equips them with advanced clothing and equipment. They carry matryoshka boiling containers that can heat food despite outside temperatures of -50 degrees Celsius and wear buoyant, waterproof gear that can protect a soldier even if they remain in water for several minutes. Rather than this being a cumbersome piece of insulating gear, this uniform still allows a solider to function easily in combat and incorporates a bulletproof vest.

To the west, US soldiers have been training with synthetic materials in their clothing, sleeping bags and tents that are designed to expel water through temperature gradients. This means that if a soldier falls or has to swim in ice-cold water they can dry themselves slowly simply through body heat.

DID YOU KNOW? *In 2007, Lewis Pugh swam at the North Pole for nearly 20 minutes in just swimming shorts, a hat and goggles!*

Cold-water immersion suit

The meticulously engineered Arctic 25 can protect its wearer for over 24 hours in frigid conditions

Gone in 60 seconds
Acting fast is important in an emergency. Thanks to having just one sealable zip the suit can be donned in less than a minute.

Waterproof
The outer layer consists of sheets of hydrophobic polyethylene, which are melted together at their edges to seal the suit.

Survival gadgets
An included safety harness and buddy line will help crew members stick together, while a light and whistle will help guide rescuers.

Ready for the drop
The suit's material is strong enough to withstand the impact of falling 10m into water.

Sole protection
Vibram soles enable the suit to tread on both extremely cold and hot surfaces without freezing or melting.

Personal life-raft
The zip can be partially opened to reveal an additional cover that can be raised over the head and upper chest to shield against wind and rain.

Extremities
As well as insulated socks, boots and gloves, face masks that use expired air to warm inhaled air can be used in extremely cold conditions.

Two Caterpillar D6N tractors were specially modified to plough snow and generate power at incredibly low temperatures

Insulation
A micro-aluminised mesh, which roughly resembles bubble-wrap, fills the suit and keeps the wearer insulated against the cold water.

Buoyancy aid
Thanks to the water-tight and air-tight outer seal, the suit is three times as buoyant as a life jacket.

Layers trump thickness
Wearing thinner layers of appropriate materials will keep you better protected than a single thick layer.

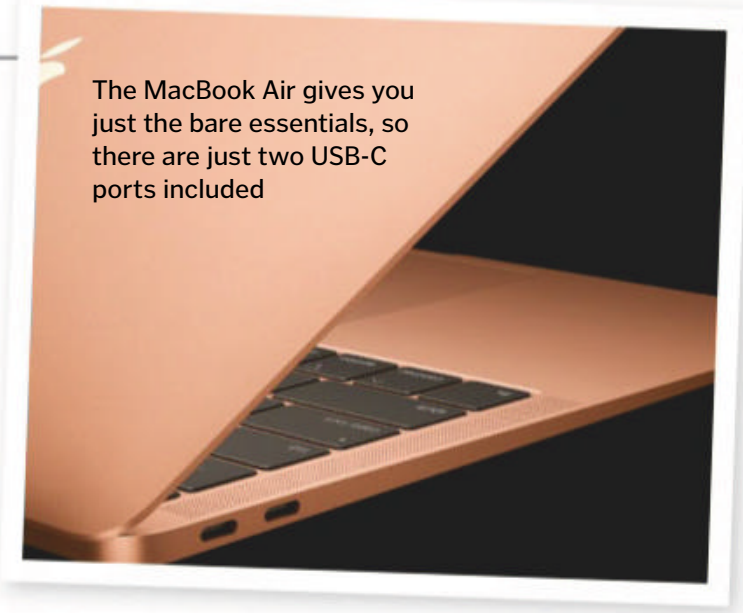
Outer layer
The external layer is made of a robust synthetic material and acts as a barrier against water, ice and wind.

Optional mid layer
An additional insulating layer will help trap body heat. If a portable power supply is needed it can also be woven in here.

Base layer
An inner layer of merino wool will both insulate and carry away moisture from sweat, keeping you dry.

Wrapping up warm

How to keep yourself dry, insulated and warm in the harshest conditions


The MacBook Air gives you just the bare essentials, so there are just two USB-C ports included

Inside the new MacBook Air

Apple's lightweight laptop has been redesigned, but just how new is it?

When it first launched the MacBook Air was the thinnest laptop in the world. Steve Jobs theatrically pulled it from an envelope to impress a crowd. But the first MacBook Air wasn't great. It wasn't very fast, it didn't have many connections, and it lacked a CD drive, which in 2008 was a pretty big deal.

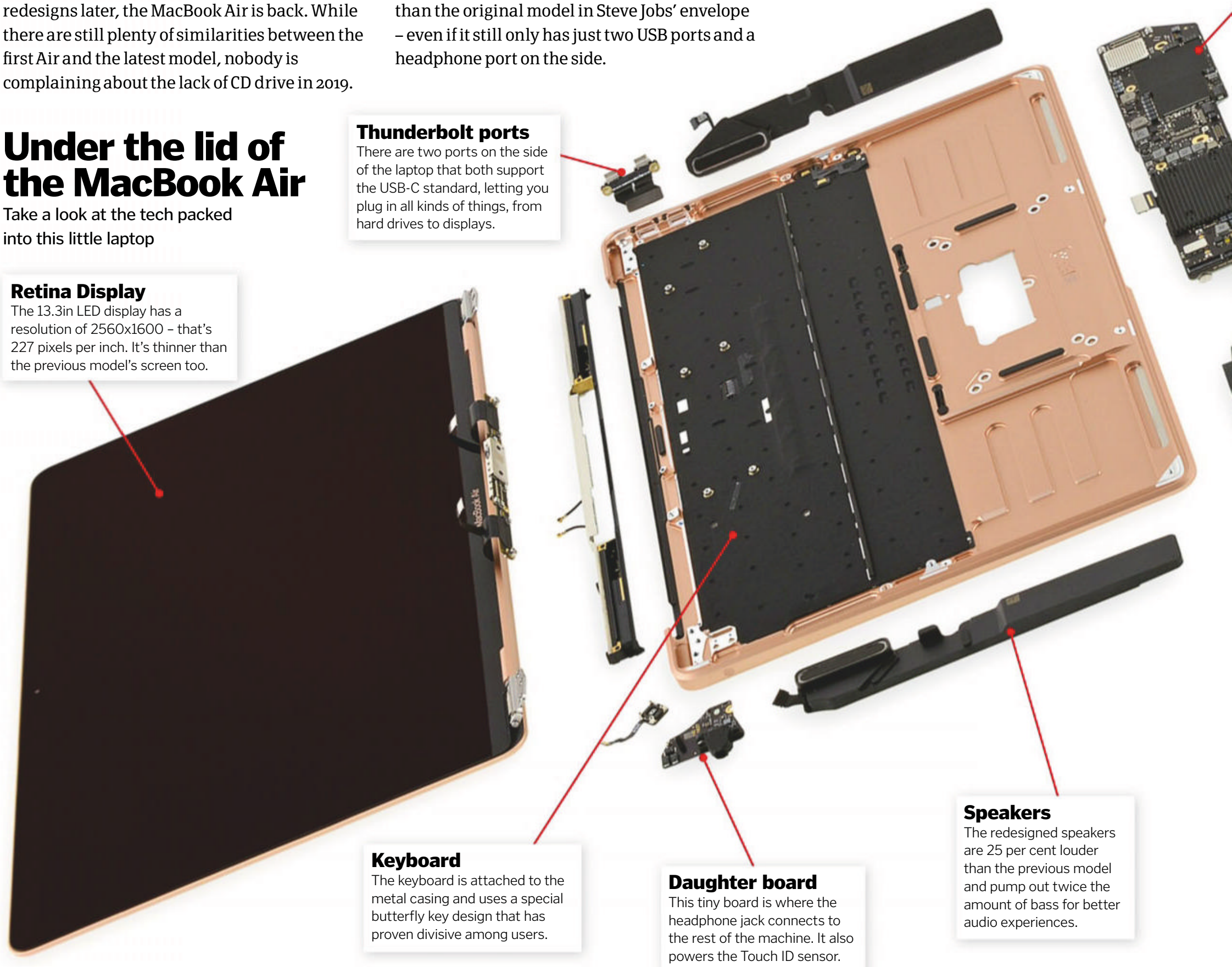
Now, more than ten years and several redesigns later, the MacBook Air is back. While there are still plenty of similarities between the first Air and the latest model, nobody is complaining about the lack of CD drive in 2019.

The new laptop packs in a Retina Display with millions of pixels, giving users a clear, bright image, and there's a Touch ID sensor, which means you can unlock your laptop and pay for things online simply by scanning your fingerprint. With a new, thinner keyboard design, a bigger trackpad, powerful chips and lots of storage, the new Air is much more capable than the original model in Steve Jobs' envelope – even if it still only has just two USB ports and a headphone port on the side.

The Air is no longer the thinnest laptop in the world (in fact, Apple's own MacBook is thinner), but this new machine has plenty of functionality, features and battery life to make up for it. But how do Apple's engineers manage to pack so much tech into such a small package? We've decided to take a look inside the laptop to find out how they do it.

Under the lid of the MacBook Air

Take a look at the tech packed into this little laptop



Thunderbolt ports
There are two ports on the side of the laptop that both support the USB-C standard, letting you plug in all kinds of things, from hard drives to displays.

Retina Display
The 13.3in LED display has a resolution of 2560x1600 – that's 227 pixels per inch. It's thinner than the previous model's screen too.

Keyboard
The keyboard is attached to the metal casing and uses a special butterfly key design that has proven divisive among users.

Daughter board
This tiny board is where the headphone jack connects to the rest of the machine. It also powers the Touch ID sensor.

Speakers
The redesigned speakers are 25 per cent louder than the previous model and pump out twice the amount of bass for better audio experiences.

DID YOU KNOW? *In 2017, after redesigning its other laptops, the MacBook Air was one of the thickest laptops Apple sold*

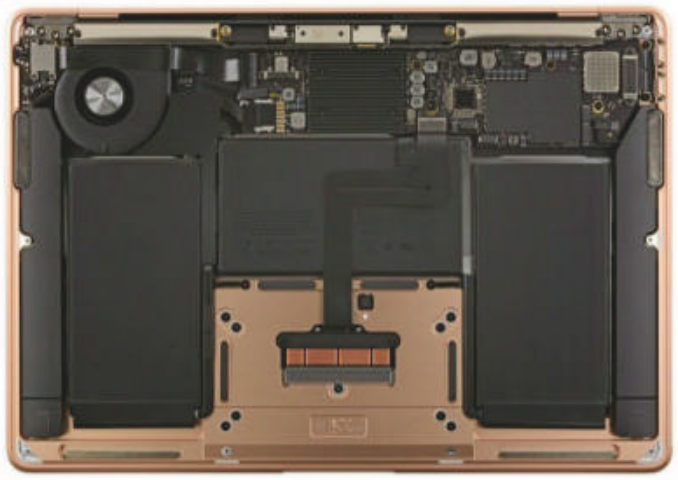
Battery
This massive battery takes up most of the case. It packs in 49.9Wh of power, which should keep the Air running for around ten hours.

Trackpad
The trackpad is pressure sensitive, allowing users to activate different features by pushing more firmly.

Logic board
This main board contains the brains of the laptop, including the Intel processor, the flash storage and the RAM.

Cooling fan
This small fan moves air around the laptop, which helps to cool things down when the processor starts getting hot.

With the bottom casing removed we can see just how tightly packed all of the internal components really are



"This new machine has plenty of functionality, features and battery life"

Touch ID

While other models have offered it as an option, the MacBook Air is the first of Apple's laptops to come with a fingerprint sensor as standard. The sensor lets you unlock your laptop safely by touching the pad. It also lets you access protected documents, settings and notes faster, and when paired with Apple Pay it means you can quickly pay for things online with a touch – no password or card details required.

It's all kept secure by a special security chip. It encrypts your data on the fly and stores any private information on the SSD in an encrypted format that can only be unlocked with your fingerprint. That way nothing private is sent over the internet, and only you can access your private data.

SATISFY YOUR HUNGER FOR KNOWLEDGE WITHIN THE PAGES OF THIS BOOK!

Find out everything that you need to know about stimulating science, trailblazing transport, transformative technology, spectacular space, humorous history and the extraordinary environment!

ON SALE NOW

FUTURE

Ordering is easy. Go online at:

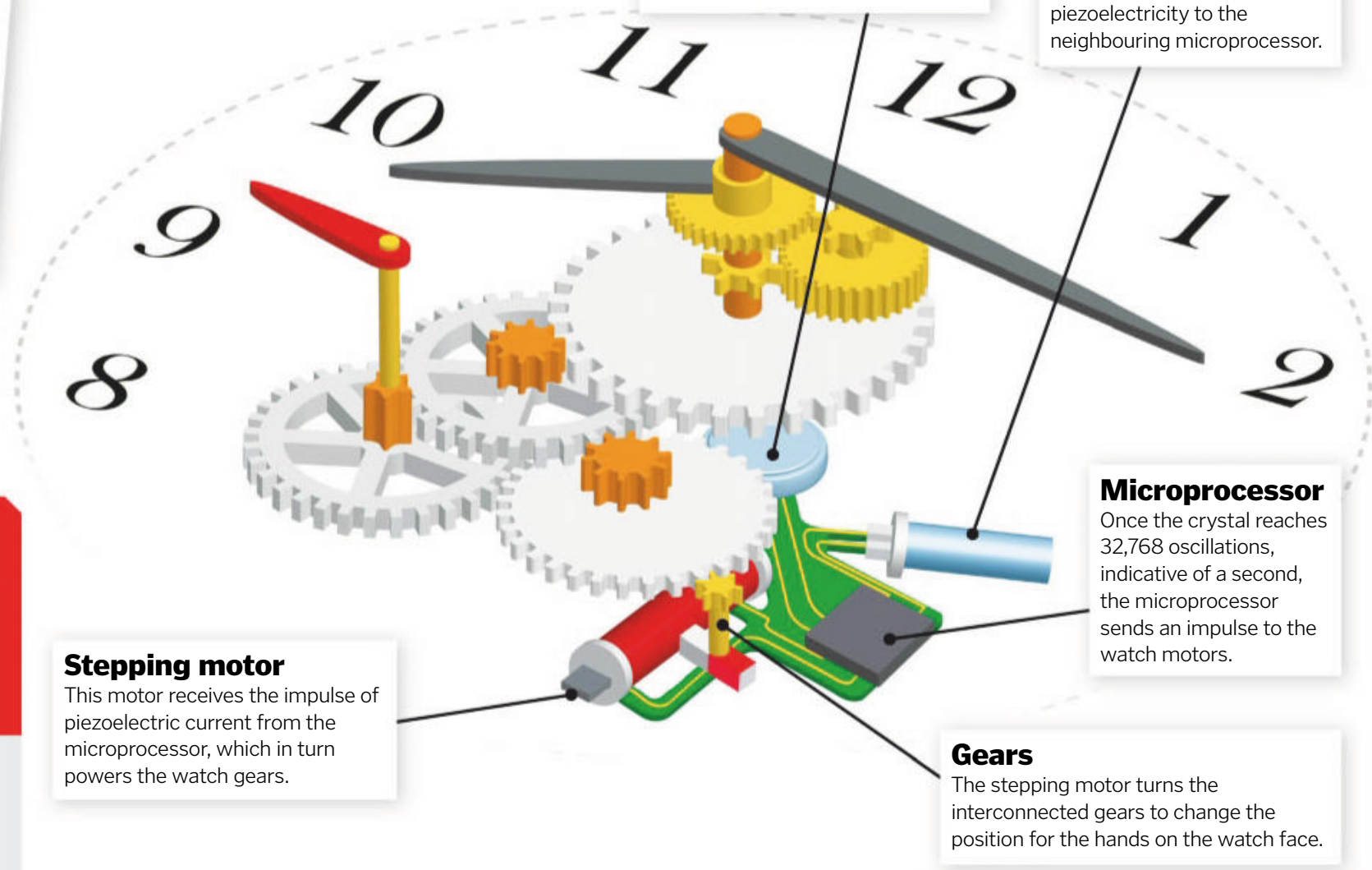
www.myfavouritemagazines.co.uk

Or get it from selected supermarkets & newsagents

The first quartz watch was the Astron, produced by Japanese manufacturer Seiko in the late 1960s

Creating time

How do these clocks translate quartz oscillations into time?



Battery
For the quartz crystal to oscillate, an electrical current must first pass through it. The watch battery supplies a small amount of current.

Quartz oscillator
This is where the quartz crystal is housed. As the electricity is passed through the crystal oscillates, feeding piezoelectricity to the neighbouring microprocessor.

Microprocessor
Once the crystal reaches 32,768 oscillations, indicative of a second, the microprocessor sends an impulse to the watch motors.

Stepping motor
This motor receives the impulse of piezoelectric current from the microprocessor, which in turn powers the watch gears.

Gears
The stepping motor turns the interconnected gears to change the position for the hands on the watch face.

5 FACTS ABOUT PUTTING PIEZOELECTRICITY TO USE

1 Actuators
Piezoelectricity is also used to trigger actuators in devices such as video cameras and smartphones. As a current passes through the piezoelectric material/crystal it expands and contracts, thereby moving the actuator.

2 Producing sound
The vibrating nature of piezoelectric material/crystals, when covered with an elastic material, will cause it to shrink and grow. In turn this produces sound waves in varying frequencies depending on the frequency of the passing electricity current.

3 An ignition source
At its most basic potential, piezoelectricity can be used to ignite a cigarette lighter. Pressing the button causes the piezoelectric crystal within to release a spark, which meets the released gas to create a flame.

4 Sensors
The piezoelectric effect allows material/crystals to detect changes in pressure, for example, and then convert that information into an electrical charge that can be used, such as in a light switch.

5 As sonar
The oscillating nature of piezoelectric material/crystals can produce sound waves that can be used to form a three-dimensional image of the seafloor.

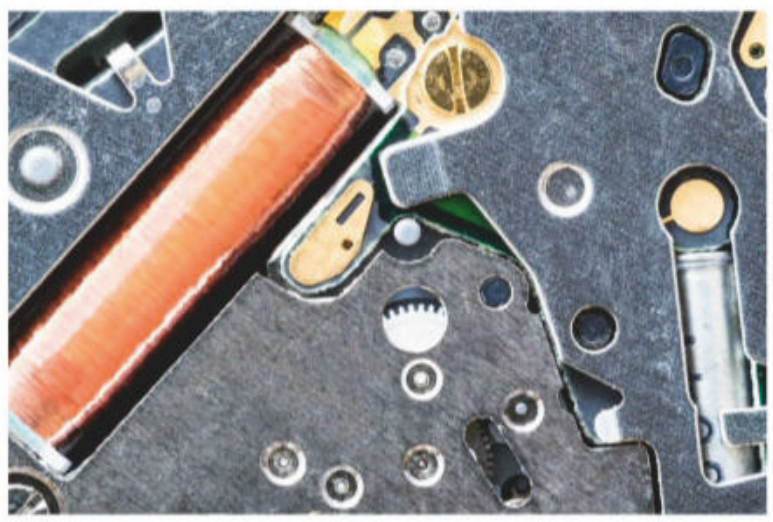
What makes a quartz watch tick?

Powered by a tiny crystal, quartz watches use natural electricity to tell the time

Created at the end of the 1960s and the start of what some say was the 'watch revolution', quartz watches flooded the global market. As precise timekeepers, these watches utilised a natural phenomenon called piezoelectricity. Discovered in 1880 by sibling physicists Pierre and Paul-Jacques Curie, piezoelectricity is an electrical flow caused by the mechanical or electrical manipulation of certain crystals with an unsymmetrical atomic structure.

Quartz at an atomic level is made up of four oxygen ions (negatively charged) and a single silicon ion (positively charged) bound in a pyramid structure. When this structure is mechanically compressed each side of the crystal is charged, one side being mainly negatively charged and the other positively. The same is true in reverse; pass a current through quartz and the crystalline structure changes, causing it to oscillate. This is known as the piezoelectric effect, but how does this make a watch tick?

When quartz is exposed to a current its oscillation becomes precise and relatively unwavering. Watchmakers take advantage of this, converting it into the tick of the second hand on a clock face. As the current from the watch battery is passed through the quartz oscillator the crystal oscillates at exactly 32,768 times a second. A neighbouring microchip receives the current from the oscillating crystals, and once it hits the 32,768th oscillation the microchip will send a single electrical impulse to the watch motor, turning the inner gears as a single tick is tocked.



The world's first quartz clock was built by two employees at Bell Telephone Laboratories, New York, US, in 1927

Roald Amundsen's research vessel, Gjøa, became stuck in the Arctic ice for almost two years during his Northwest Passage expedition of 1903–1906

RACE TO THE POLES

How pioneering explorers battled extreme conditions to reach the ends of the Earth

Words by **Jackie Snowden**

By the turn of the 20th century few places on Earth remained uncharted. Since the Age of Discovery humans had developed the means to cross oceans and explore continents in the interest of developing trade routes and expanding empires. The frozen expanses of the poles presented extreme challenges but offered different incentives: the irresistible lure of the unknown and the glory of getting there first.

PEARY VERSUS COOK

The geographical North Pole lies at the latitude of +90° on a thick shelf of sea ice. The frozen sea shifts with the seasons, making journeys across the Arctic particularly treacherous. Explorers also face temperatures that can drop to -50 degrees Celsius, wind speeds of up to 90 kilometres per hour and the prospect of being hunted by polar bears. After several failed expeditions in the 1800s, in 1909 two successful missions to the North Pole by American explorers were, curiously, reported within a week of each other.

The first was Dr Frederick Cook who, accompanied by native hunters from Greenland, claimed to have reached the pole on 21 April 1908. The team left from Annoatok, Greenland, in February 1908 and travelled an average of 24 kilometres per day using dog sleds, plus a collapsible boat to cross the water where necessary. According to Cook's memoirs he used a sextant to determine his latitude and calculated his position as "a spot which was as near as possible" to the North Pole. However, a perilous return journey over the fractured, drifting ice delayed their return to civilisation and meant they were unable to send word home for another 14 months.

In August 1908, while Cook was missing, presumed dead, his former colleague US Navy Commander Robert Peary set off on what was his ninth Arctic expedition. Using the so-called 'Peary system', his 50-man party rode dog sleds to perform a relay to drop supplies ahead along the route. Unlike Cook, Peary's team did not take boats, so when the ice fractured they were sometimes left stranded for days until the gaps closed up again. When they were moving they covered an average of 21 kilometres per day. Peary took regular sextant measurements to make sure they were still heading north. On 6 April 1909 he recorded a latitude of just over +89° and wrote in his journal, "The Pole at last! [...] my dream and ambition for 23 years. Mine at last."

The announcements of their respective successes almost coincided due to Cook's homeward delays and Peary's remarkably fast return trip. Cook's story was reported on 2 September 1909, while Peary's was published on 7 September, but their achievements were overshadowed by the bitter feud that followed. Almost immediately Peary and his expedition benefactors dismissed Cook's attempt. Peary even took the matter to Congress in order to get the government to officially recognise his achievements instead of Cook's claims.

To this day there are doubts regarding both Cook and Peary's claims; the explorers' accounts and any remaining evidence from both expeditions have been reexamined many times. Questions have been raised about the accuracy of both men's latitude measurements, reported travel speeds and unusual omissions from their journals. It's unlikely that there will ever be a definitive answer as to how close each man truly came to the North Pole, and who – if either of them indeed did – reached it first.

AMUNDSEN VERSUS SCOTT

Less than two years after Cook and Peary's feats first made headlines, preparations for another head-to-head polar race were just getting underway on the other side of the world. In January 1911 two teams of explorers arrived at the Antarctic determined to be the first to reach the South Pole.

The geographical South Pole is located at the latitude of -90° on one of the most inhospitable places on the planet. Antarctica is the coldest place on Earth, holding the record for the lowest observed temperature (at ground level) of -89.2 degrees Celsius. The majority of the inner ice shelf is between two and four kilometres thick, so explorers may experience altitude sickness as they attempt to cross the continent. Antarctica is also home to some of the world's strongest winds; certain areas can experience gusts of over 198 kilometres per hour. What's more, the continent is surrounded by the roughest and stormiest waters on the planet – the Southern Ocean – so both teams faced significant dangers before their expeditions even began.

The competing expeditions were led by Norwegian Captain Roald Amundsen and British Captain Robert Falcon Scott, both of whom were already renowned explorers. Scott had previously tackled the Antarctic during the 1901–1904 Discovery Expedition with fellow explorers Ernest Shackleton and Dr Edward Wilson, making it to -82° latitude – closer to the pole than anyone had reached before. Scott had been granted £20,000 funding from the government for the new expedition, and his preparations were given a lot of media attention.

While Scott's expedition intentions were public, Amundsen kept his own polar plans secret. He was already organising an Arctic expedition when Peary and Cook's claims shattered his lifelong dream of being first to the North Pole. Rather than abandoning the expedition altogether, he revised the plans to make an attempt to the South Pole instead. Even Amundsen's own crew were still under the impression they were heading to the Arctic until he revealed the truth en route.

Scott's team arrived in Antarctica on 4 January 1911 at Cape Evans. While they were setting up base camp and preparing for the trek ahead they were completely unaware that Amundsen's crew had landed just 640 kilometres away in the Bay of Whales on 14 January. Both teams spent most of the year making preparations for the expeditions, laying supply drops along their respective routes before setting off in the Antarctic spring – Amundsen on 20 October and Scott on 1 November.

Key differences between the tactics and equipment of the two crews spelled success for

Robert Peary, 1856–1920

This cartoon illustrates Peary and Cook's feud but also highlights how little was known about the North Pole at the time – penguins don't live in the Arctic!

Polar gear

For any explorer, having the right clothing and equipment can be the difference between life and death

Goggles
Sunlight reflecting off the ice and snow can cause painful temporary vision loss. Goggles with smoked glass were worn by Scott's team to protect against this snow blindness.

Windproof layers
Outdoor fashion brand Burberry provided both Scott and Amundsen's teams with coats and tents made from the company's breathable and waterproof fabric called gabardine.

Native knowledge
Amundsen applied what he had learned from the Inuits in the Arctic to his South Pole expedition. His team wore loose layers and wolfskin fur suits.

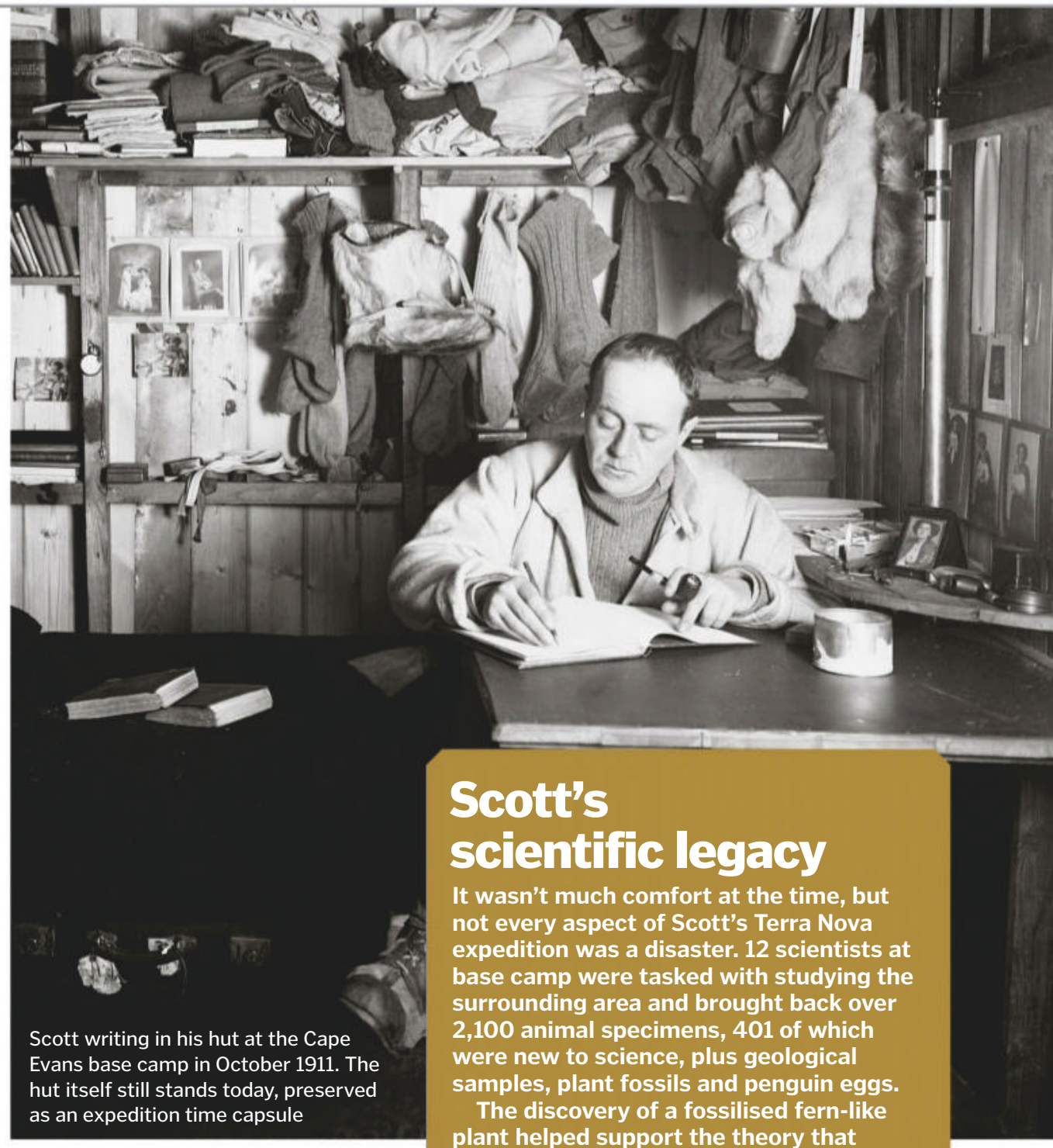
Gloves
In order to be warm enough to protect the extremities, gloves or mittens were often so thick they restricted movement. Explorers had to risk exposing their hands to the elements to perform more intricate tasks.

Scientific equipment
Cameras and navigational equipment were bulky, but these devices were vital to track progress and document the journey.

Boots
Scott's team wore felt-lined, reindeer fur boots that were stuffed with hay to trap more air and provide extra insulation.

Furs
Scott's team wore less fur than Amundsen's. Since they were man-hauling some of their gear they would have overheated in heavy furs.

Amundsen's team (above) reached the South Pole 34 days before Scott's (below)



Scott writing in his hut at the Cape Evans base camp in October 1911. The hut itself still stands today, preserved as an expedition time capsule

one and tragedy for the other. Amundsen's small, specialised team included champion skiers and expert dog handlers. They had specially modified skis, wolfskin furs, windproof suits and knew to wear their layers loosely to avoid sweating so much – a tip Amundsen had learned from the Inuits during a previous Arctic expedition. They reached the South Pole on 14 December and returned safely to base camp on 25 January 1912.

Scott's team was less experienced with both the cold weather and skiing. They brought ponies and motor sleds, but this soon proved to be a grave mistake. Both were unable to cope with the extremes of Antarctica; the sleds failed and were abandoned, and the weakened ponies were eventually shot for food. They reached the pole on 17 January 1912, devastated to find the Norwegian flag already firmly planted there.

Scott's team were suffering from malnutrition, starvation, frostbite and hypothermia as the temperatures dropped to around -30 and -40 degrees Celsius. None of them survived the return to base camp. Scott ran out of rations and fuel and was trapped in his tent by a blizzard, despite being just a few miles away from a supply stash. His tragic last journal entry on 19 March read, "We shall stick it out to the end, but we are getting weaker, of course, and the end cannot be far. It seems a pity, but I do not think I can write more."

Amundsen sent word of his historic success on 7 March 1912 and was duly hailed a hero. However, his glory was later eclipsed when the world learned of the fate of Scott and his men, who were seen as martyrs.

As with Peary and Cook, Amundsen and Scott's journeys have been reexamined over the years – not to dispute whether or not they reached the South Pole, but to determine the combination of factors that led to Scott's failure.

THE END OF AN ERA

These pioneering expeditions of the early 20th century were among the last of what became known as the 'heroic' age of polar exploration. These men were admired for the sheer determination it took to face such harsh conditions with limited resources, pushing their physical and mental strength to the absolute limit in the pursuit of immortality.

This courageous era of discovery drew to a close after World War One, when engineering and technological advancements made such journeys – relatively speaking – much more straightforward to complete.

Scott's scientific legacy

It wasn't much comfort at the time, but not every aspect of Scott's Terra Nova expedition was a disaster. 12 scientists at base camp were tasked with studying the surrounding area and brought back over 2,100 animal specimens, 401 of which were new to science, plus geological samples, plant fossils and penguin eggs.

The discovery of a fossilised fern-like plant helped support the theory that Antarctica was once part of a much larger continent (now known as Gondwanaland). The penguin eggs were collected to try and explore the possible connection between birds and the dinosaurs, which was a relatively new idea at the time.

Since the first polar pioneers people have continued to travel to both the Arctic and Antarctic in the name of science. Today there are a whole host of research stations in the polar regions that are teaching us more about our planet. Antarctica's remote Concordia Research Station is even used to help train astronauts, preparing the next generation of explorers for the uncharted areas that lie beyond Earth.

Scott's team collected zoological, meteorological and geological data about Antarctica

TRAGEDY AND TRIUMPH

What went right and wrong for Amundsen and Scott?

Robert Falcon Scott, 1868–1912

Roald Amundsen, 1872–1928 (disappeared)

14 Dec 1911
Amundsen reaches the South Pole. The team spend several days defining its exact position with sextant measurements.

17 Jan 1912
Scott and his team reach the South Pole, only to discover that Amundsen has beaten them to it.

21 Nov 1911
The team reach the Antarctic Plateau after climbing the newly discovered Axel Heiberg Glacier, which Amundsen named after one of the expedition's financial sponsors.

Photos from Peary (top) and Cook's (above) expeditions from when they believed they'd reached the North Pole

Axel Heiberg Glacier

Beardmore Glacier

17 Feb 1912
Edgar Evans dies after falling into a coma. It's thought he sustained a head injury after a fall while descending Beardmore Glacier.

16 Mar 1912
Lawrence Oates, suffering from severe frostbite, utters his famous last words before leaving the tent during a blizzard: "I am just going outside and may be some time."

20 Oct 1911
Once spring arrives Amundsen sets off again, this time with a party of five.

8 Sept 1911
Amundsen's party of eight set off from base camp in the Bay of Whales. They soon turn back after finding the conditions were still too harsh.

29 Mar 1912
Trapped by the blizzard less than 18km away from their largest supply stash, Scott writes his last journal entry. He, Wilson and Bowers die shortly after. A search party finds their bodies in November.

Scott's pole team
Robert Falcon Scott: Team leader
Edgar Evans: Royal Navy petty officer
Lawrence Oates: Army captain
Dr Edward Wilson: Chief scientist
Henry Bowers: Royal Indian Navy lieutenant

Amundsen's pole team
Roald Amundsen: Team leader
Olav Bjaaland: Champion skier
Helmer Hanssen: Expert dog sled driver
Sverre Hassel: Expert dog sled driver
Oscar Wisting: Naval officer

Amundsen's base camp (~1,285km to South Pole)
Amundsen's team returned safely to base camp on 25 January 1912 and left Antarctica aboard his ship, Fram, a few days later. Amundsen sent telegrams reporting his successful expedition on 7 March from Tasmania.

Scott's base camp (~1,380km to South Pole)
The Terra Nova team set off from base camp at Cape Evans on 1 November 1911. Using Ernest Shackleton's Nimrod expedition route they headed for the Antarctic Plateau via Beardmore Glacier.

DID YOU KNOW? *Scott's vitally important fuel cans leaked because their leather seals deteriorated in the freezing conditions*

It is estimated that Antarctica has lost 2.71 trillion tons of ice since 1992

Ice cores are also used to determine past climate change

Drilling into ancient Antarctica

How the ANDRILL project is revealing Earth's past and predicting its future

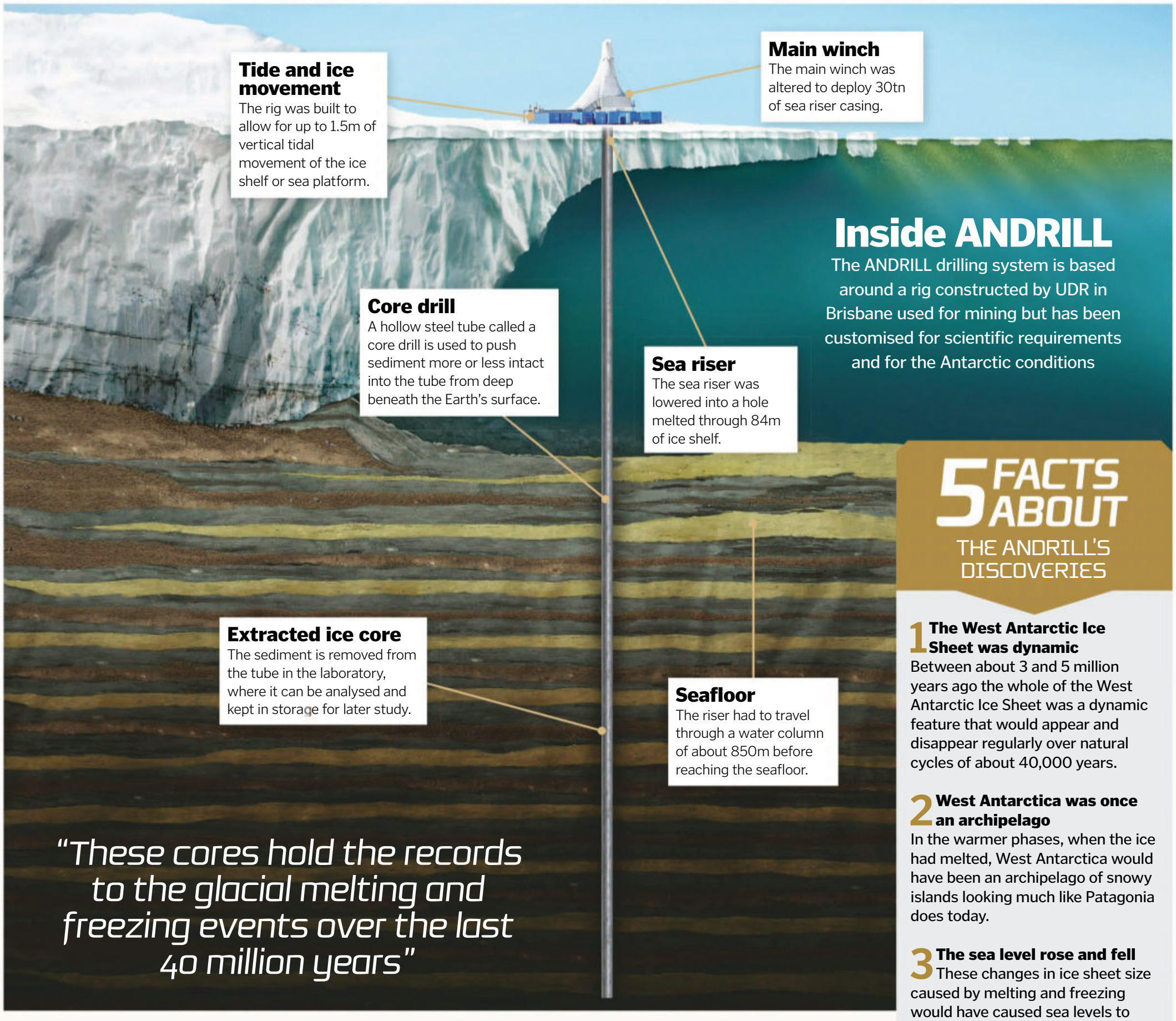
Beneath our feet there are layers of rock that tell the story of our planet. From the crumbly pale limestone to the hardened beds of grey shale, each layer is a unique snapshot of Earth's natural history.

ANDRILL (the Antarctic Drilling Project) has a mission to recover this history. The two sites of their first drilling project (the McMurdo Ice Shelf Project Drilling from 2006 to 2007 and the Southern McMurdo Sound Project Drilling from 2007 to 2008) were based in the McMurdo region of Antarctica. The McMurdo Ice Shelf drilling rig stood in water nearly one kilometre deep and floated on ice 84 metres thick. The project aimed to pull giant cores of sediment from the ground to uncover the secrets locked away in the rock that tell of the glacial and interglacial changes in the Antarctic region.

At the two sites the researchers drilled through the ice shelf of the Antarctic and into the sediment to bring the solid cores of rock back to the surface so they can be analysed. The cores held the records to the glacial melting and freezing events over the last 40 million years. By studying them researchers have been able to determine the speed and frequency of fluctuations that have occurred over the period.

The sediment core obtained from the Southern McMurdo Project dates to over 20 million years ago. Coupled with some clever mathematical modelling, scientists used the samples of rock to predict the areas of future global warming and further their understanding of the speed, size and frequency of melting and freezing. This type of information will be vital in the fight against climate change.

Drill rods await use just outside the ANDRILL facility in Antarctica



Inside ANDRILL

The ANDRILL drilling system is based around a rig constructed by UDR in Brisbane used for mining but has been customised for scientific requirements and for the Antarctic conditions

5 FACTS ABOUT THE ANDRILL'S DISCOVERIES

1 The West Antarctic Ice Sheet was dynamic
Between about 3 and 5 million years ago the whole of the West Antarctic Ice Sheet was a dynamic feature that would appear and disappear regularly over natural cycles of about 40,000 years.

2 West Antarctica was once an archipelago
In the warmer phases, when the ice had melted, West Antarctica would have been an archipelago of snowy islands looking much like Patagonia does today.

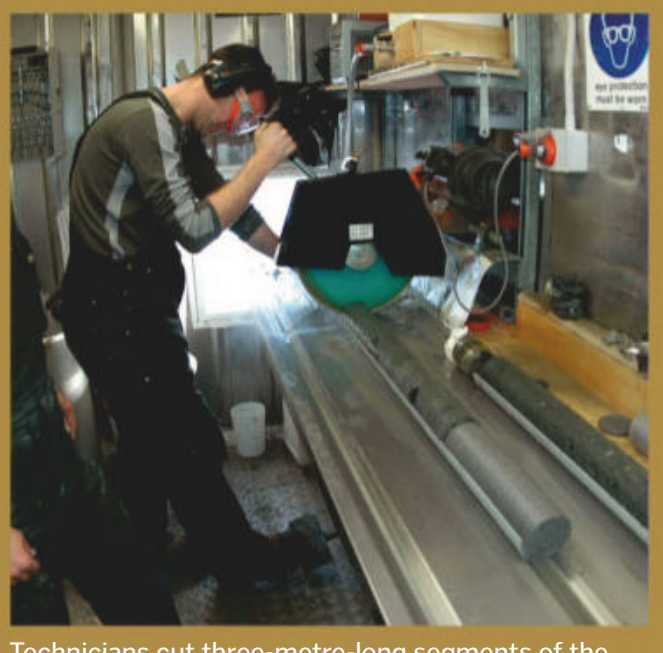
3 The sea level rose and fell
These changes in ice sheet size caused by melting and freezing would have caused sea levels to rise and fall by up to six metres each cycle.

4 The Ross Sea region was once similar to the coast of southwestern New Zealand
Researchers expect from the findings that around 17.5 million years ago climatic conditions in the Ross Sea region were similar to those of the coastal margin of Southwestern New Zealand today.

5 There were higher levels of carbon dioxide than today
During the periods of relative warmth the researchers found that carbon dioxide levels in the atmosphere were above present levels, though they remained within the range of predicted levels for the end of this century.

Determining past climate change

Sediment cores can provide researchers with a treasure trove of information. The layers of rock can indicate such things as the presence of volcanic ash, while microfossils and gasses trapped within the rock can provide valuable details about the atmosphere. This can help determine past climate change. There are other ways to do this without drilling hundreds of metres into the Earth's surface, such as taking samples of ocean sediment. Buried into ocean sediment are calcium carbonate shells from creatures that once walked the Earth. Scientists can use these shells to determine the climate of the environment in which they lived, as they usually only live within narrow temperature ranges. Other techniques include studying the gaps between the circular lines of a tree trunk (dendrochronology) and calculating the ratio of oxygen isotopes that are present in ice cores.


Technicians cut three-metre-long segments of the ANDRILL core into one-metre lengths in the lab

Concept Kids: Animals

A quirky children's guessing game with a distinctive art style

■ Publisher: **Asmodee** ■ Price: **£22.99** ■ Number of players: **2–12** ■ Recommended age: **4+** ■ Typical game time: **20 minutes**

You don't need to dress the classic game of 'Animal, Vegetable, Mineral' up much for a board game adaptation, and that's exactly what Asmodee hasn't done for its co-operative version of *Concept*.

Designed for children with a limited vocabulary (in any language), it uses visual rather than literal cues to describe animal characteristics. The rules are very simple: the adult has to guess what animal is on the card by asking the children closed questions (that only have 'yes' or 'no' answers). For every question or guess, one of the children places a ring around a characteristic depicted on the board that helps describe the animal. For example, for a cat you might place a ring around the image of fur, the four legs image and the house image.

The rules don't define a limit to the number of guesses or give a time limit as such, probably because this is more of an engaging learning experience than a competitive board game. The USP of *Concept Kids: Animals* is the fantastic illustration work by artist Eric Azagury, which provide a simple but effective means of non-verbal communication between adult and child.

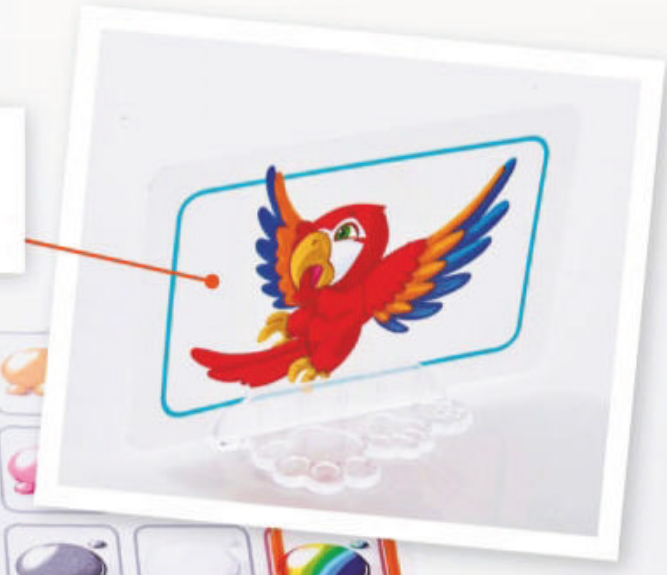
If we were to make a small criticism, it would be that the range of animal characteristics on the board isn't quite what it could be, leaving us (two adults) struggling to describe some of the animals, especially those from the harder red deck. However, this is still a fun and suitably challenging game for parents and children to play together.

Animal guesswork

There are two straightforward ways to play

Give us a clue
If they can't guess, or they make a wrong guess, the describer places another ring. This continues until the guesser gives up or guesses the animal.

Is it a...?
The guesser can't see the animal and must ask a question or try to guess what's on the card.



Easy game
For an easier game, take 12 cards from the blue-bordered deck, place them face-down and put one in the card slot.

Hard game
The red-bordered cards feature animals that are more diffcult to guess. Take 12 of these for a harder game.

Describe the animal
The person describing the animal places a ring around an illustration on the board they think describes a characteristic of the animal.

Endgame Scoring
The guesser gets 1 point for each correct guess. When all 12 cards are exhausted they can see what animal rating their score has achieved.

Special offer for readers in **North America**

4 FREE issues

When you subscribe*

"The action-packed science and technology magazine that feeds minds"

Order hotline **+44 (0)344 848 2852**

Online at **https://www.myfavouritemagazines.co.uk/hiwusa**

***Terms and conditions** This is a US subscription offer. 4 free issues refers to the US newsstand price of $9.99 for 13 issues being $129.87, compared with $87 for a subscription. You will receive 13 issues in a year. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices are correct at point of print and subject to change. Full details of the Direct Debit guarantee are available upon request. UK calls will cost the same as other standard fixed-line numbers (starting 01 or 02) included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: **bit.ly/magtandc**. Offer ends 30 April 2019.

OFFER EXPIRES 30 Apr 2019

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

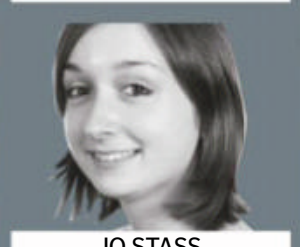
Who's answering your questions this month?


JODIE TYLEY


TOM LEAN


LAURA MEARS


JAMES HORTON


JO STASS

Want answers?

Send your questions to...

How It Works magazine

@HowItWorksmag

@howitworks@futurenet.com

Where is our Sun's habitable zone?

Skylar Jones

According to recent simulations, the habitable zone starts at about 142 million kilometres from the Sun. Earth's average distance from the Sun is approximately 150 million kilometres. **LM**

How do the coloured stripes stay so neat in toothpaste?

Gareth Bridges

■ Each coloured stripe has the same 'rheology', meaning they have the same thickness and move at the same speed when pressure is applied. The stripes become thinner when the toothpaste is squeezed, but they remain in neat lines because of this property. **JT**

Are there fossils in Antarctica?

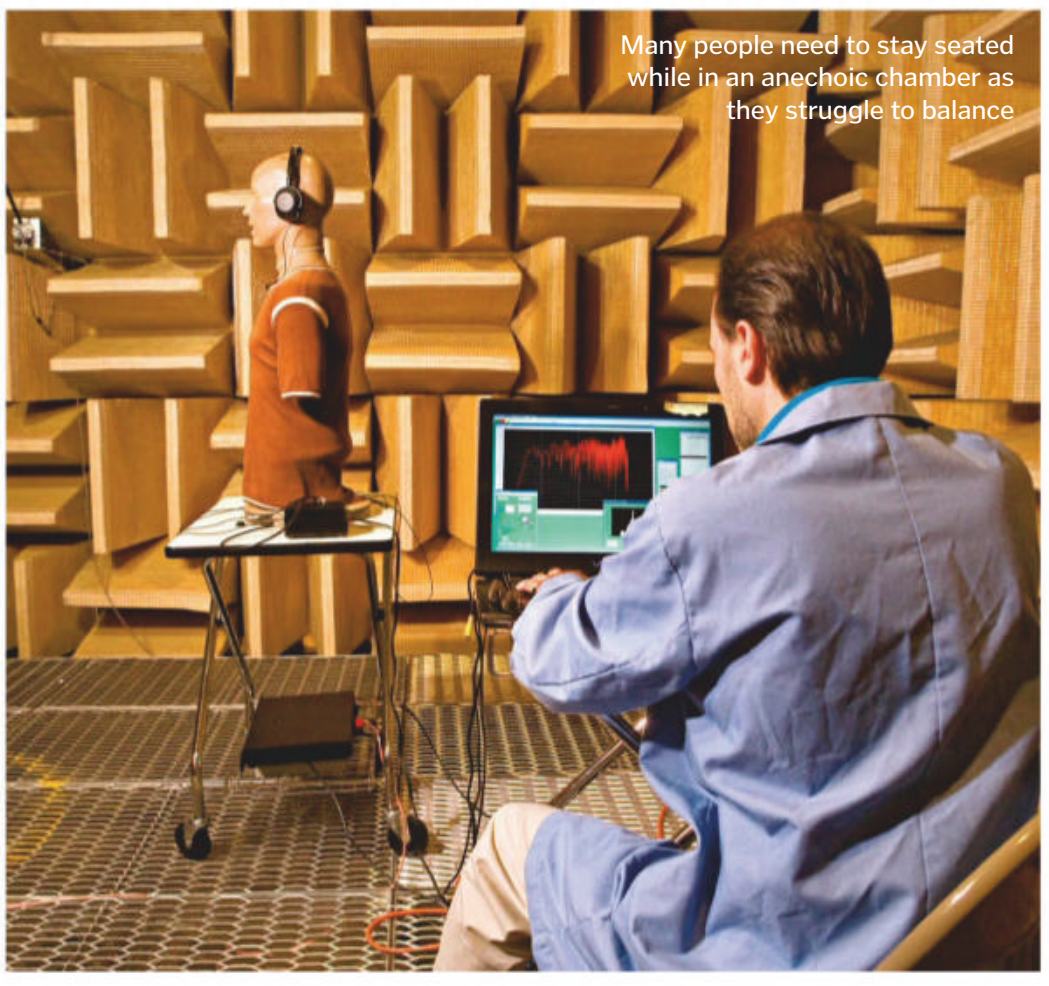
Titus Ridgely

■ Yes. Thanks to fossils scientists know that over 260 million years ago Antarctica was covered with green forests and that dinosaurs later roamed the continent. However, today's challenging Antarctic climate means that much of the area remains unexplored by humans, so it is thought that there are many more fossils yet to be discovered. **JS**

Do anechoic chambers really drive people mad?

Lucy Downes

■ No, but they can make walking difficult! An anechoic chamber is a room that's specially designed to absorb all sound. They're typically used for testing the noise levels of certain products, but when a person goes inside the experience can be quite disorientating. When it is so quiet you can hear your own heart beating and it can be difficult to find your balance. This is because we use sound to orient ourselves, so without any audio cues you struggle to manoeuvre your body. **JS**



Many people need to stay seated while in an anechoic chamber as they struggle to balance

BRAIN DUMP

What is dog chocolate made of that makes it safe for them to eat?

Nicola Burke

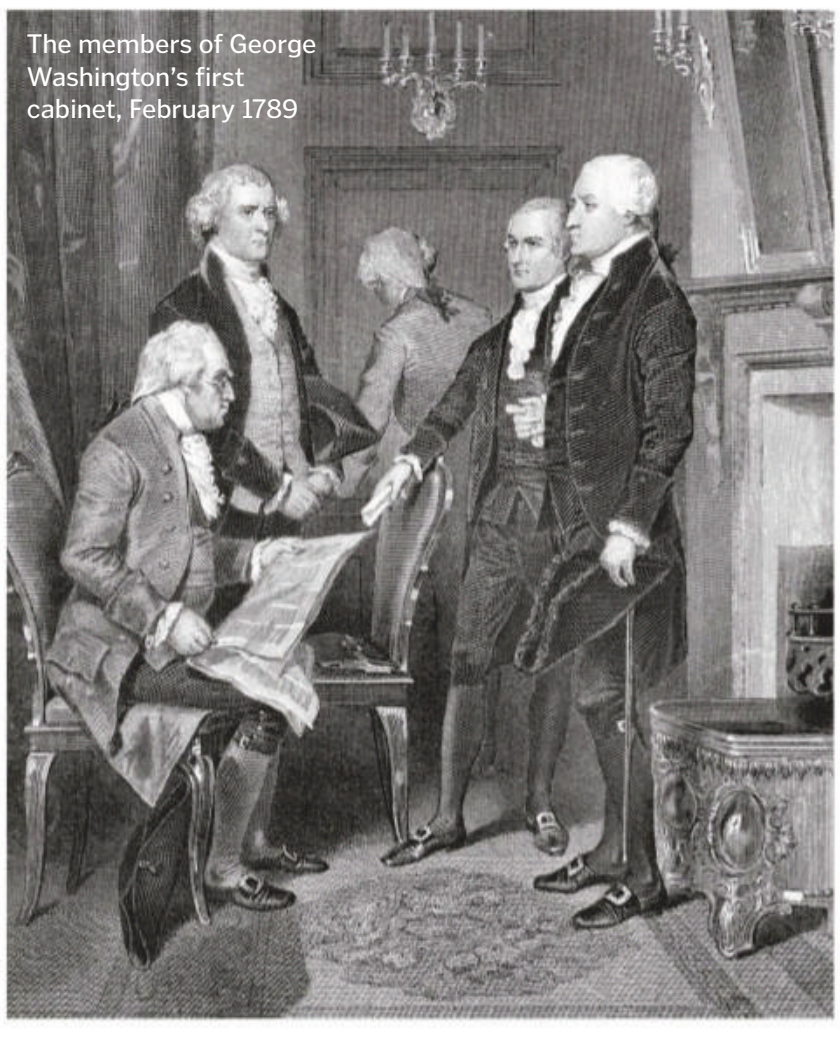
Chocolate contains a toxic substance called theobromine, which human bodies can process quickly but pooches cannot. If they get their paws on chocolate it can be fatal. However, there is a safe substitute that's used in some dog treats. It's called carob – a brown powder extracted from the pods of a carob tree, which is native to the Mediterranean. The fact that it doesn't contain theobromine means it's non-toxic to dogs, but its sweet flavour means they won't be able to tell the difference. **JT**

Keep chocolate out of your dog's reach unless it's made from carob

How much oil is currently left in the world's reserves?

Chuck Tanner

According to the Organization of the Petroleum Exporting Countries (OPEC), the world had around 1,482,773 million barrels of crude oil reserves in 2017, a 0.4 per cent decrease on the 2016/17 figures. **JS**

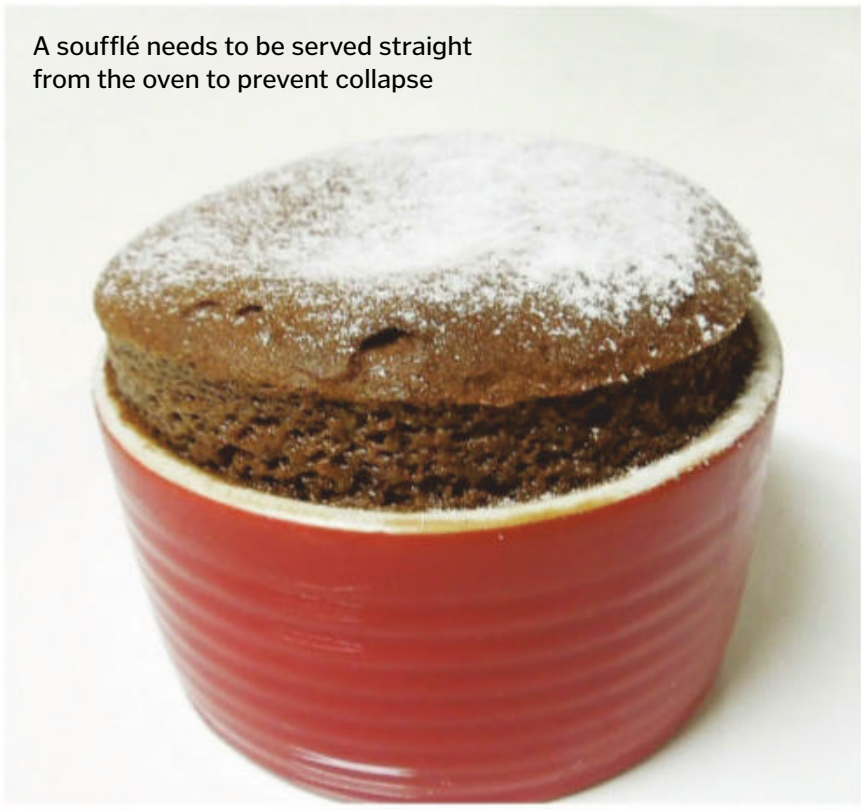


The members of George Washington's first cabinet, February 1789

How was the first US president elected?

Susanna Rudd

George Washington was unanimously elected in 1789. Only white men who owned property were allowed to vote for people to represent their state, who in turn voted for the president and vice president. In the 18th century state electors cast two votes, with the most popular candidate becoming president and the person in second place becoming vice president. This system was flawed as there was no distinction between the two votes, and it was abused in 1796 when electors only cast one vote to ensure their preferred choice won, so the vice president became the president's rival. This changed in 1804 and separate votes were cast. **JT**

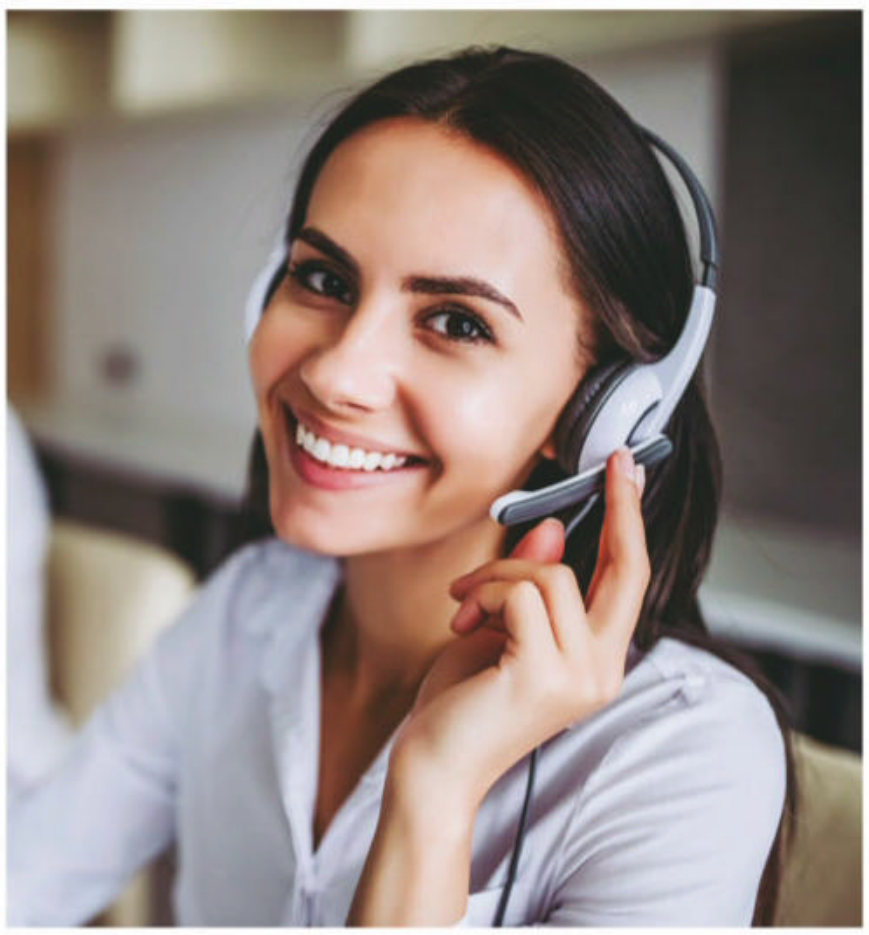


A soufflé needs to be served straight from the oven to prevent collapse

What causes soufflés to sink?

Jemima De La Rue

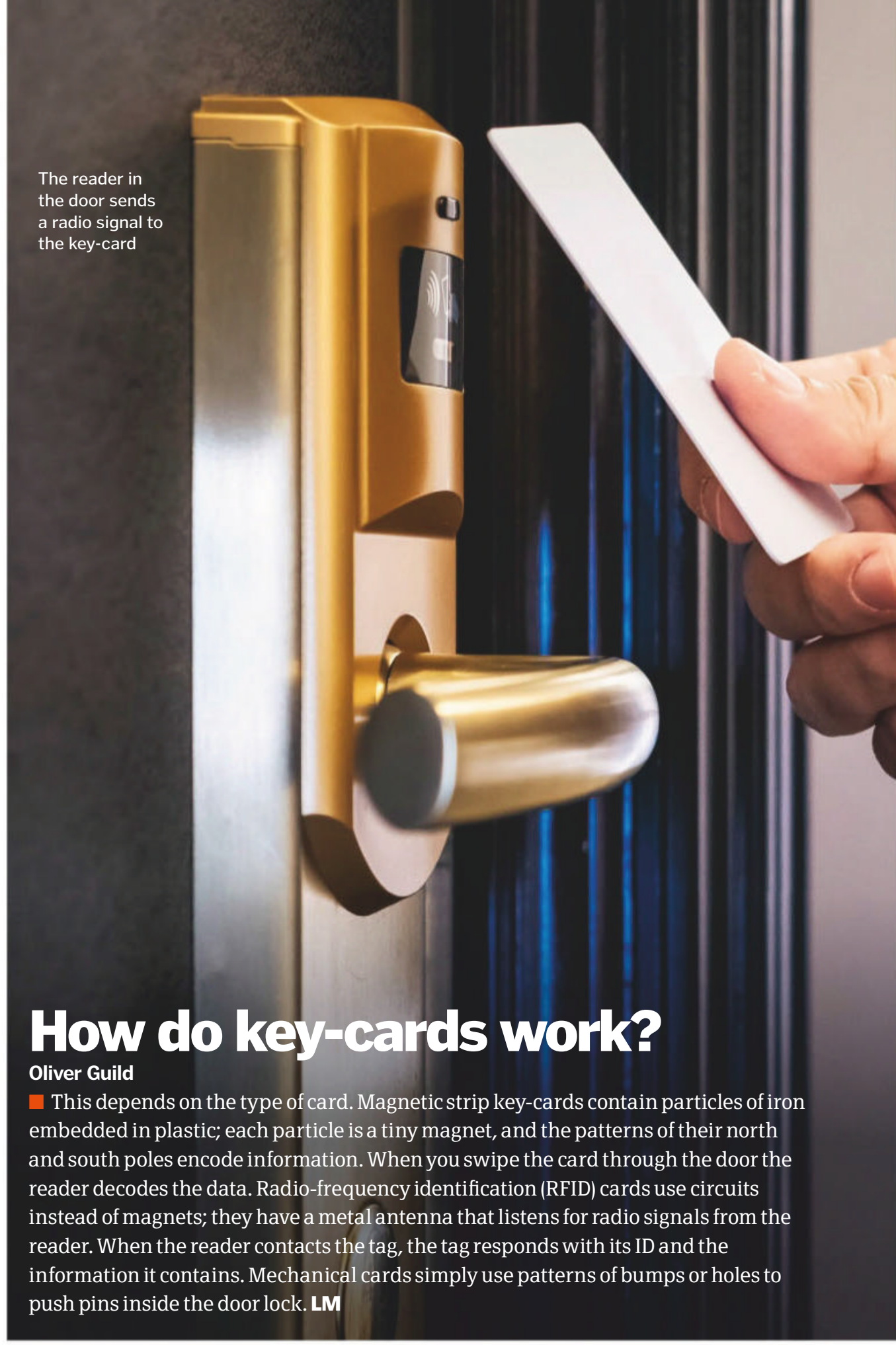
A soufflé is made by whipping egg whites and then folding them into egg yolks. When you whip the egg whites you form bubbles of air encased in a protein skin. Then, when you put the mixture in the oven, the bubbles expand and the protein stiffens, causing your soufflé to rise. The tricky part is preventing these fragile bubbles of air from bursting. Over-beating the egg whites, folding them into the yolks too vigorously and cooking at the wrong temperature or for the wrong amount of time can all cause the air to escape, resulting in a collapsed dessert. **JS**



Are any jobs already being taken over by AI?

Nelson Parker

AI is already displacing the human workforce in call centres, as smart Chatbots have become commonplace. Administration and secretarial jobs are likely to be most at risk in the near future. **JH**

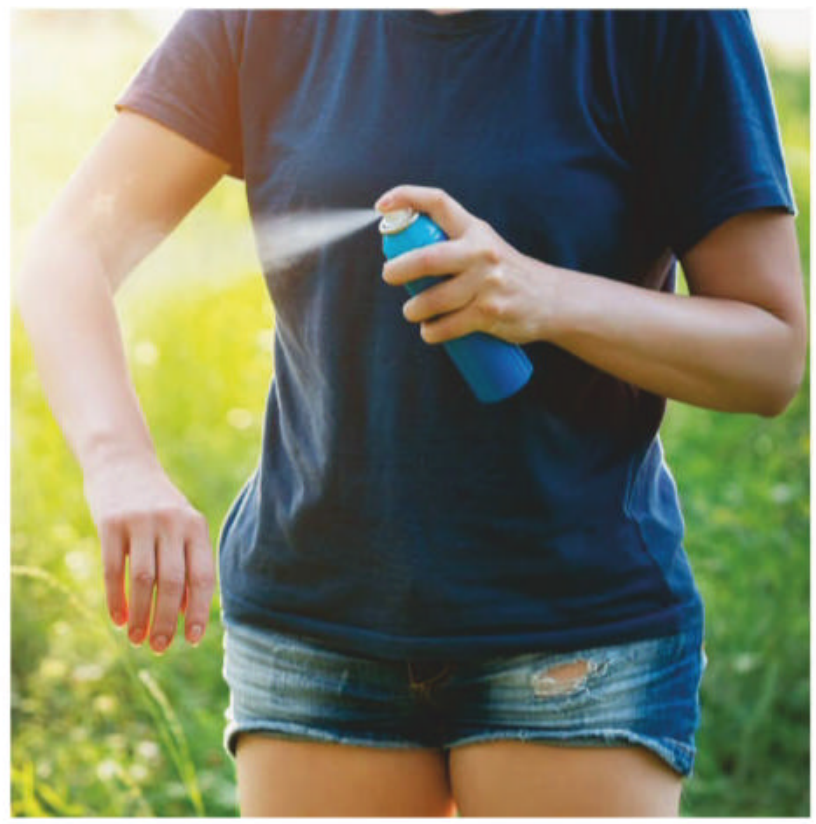


The reader in the door sends a radio signal to the key-card

How do key-cards work?

Oliver Guild

This depends on the type of card. Magnetic strip key-cards contain particles of iron embedded in plastic; each particle is a tiny magnet, and the patterns of their north and south poles encode information. When you swipe the card through the door the reader decodes the data. Radio-frequency identification (RFID) cards use circuits instead of magnets; they have a metal antenna that listens for radio signals from the reader. When the reader contacts the tag, the tag responds with its ID and the information it contains. Mechanical cards simply use patterns of bumps or holes to push pins inside the door lock. **LM**

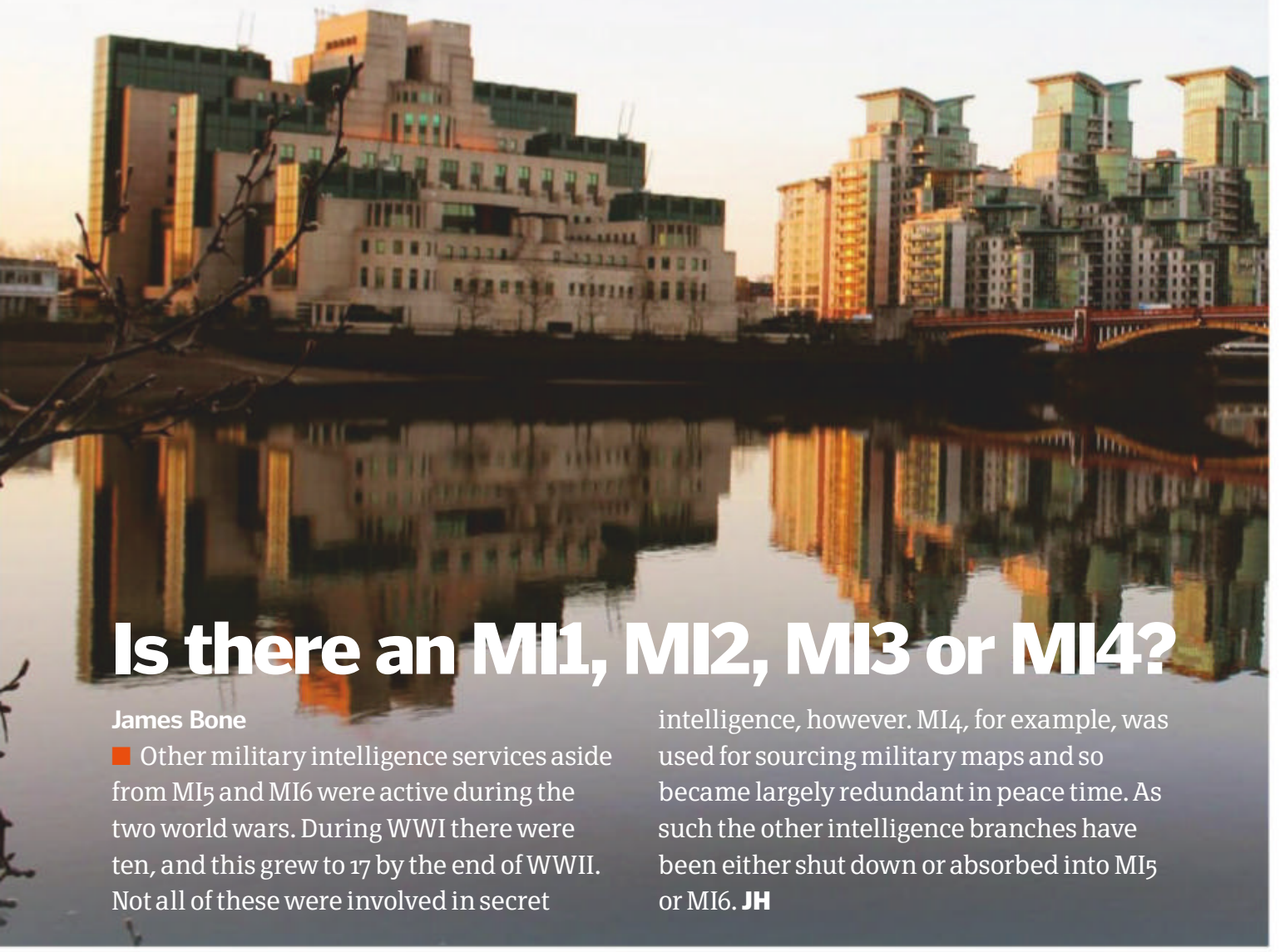


How do insect repellents work?

Tina Gomes

Insects are attracted by the chemicals that we give off, such as those in sweat and even the carbon dioxide that we breath out. Repellents work by masking these chemicals, effectively confusing insects' sense of 'smell', making it harder for them to detect you. **TL**

BRAIN DUMP



Located at Vauxhall Cross, the SIS Building has housed the Secret Intelligence Service since 1994

Is there an MI1, MI2, MI3 or MI4?

James Bone

Other military intelligence services aside from MI5 and MI6 were active during the two world wars. During WWI there were ten, and this grew to 17 by the end of WWII. Not all of these were involved in secret intelligence, however. MI4, for example, was used for sourcing military maps and so became largely redundant in peace time. As such the other intelligence branches have been either shut down or absorbed into MI5 or MI6. **JH**

What colour is a mirror?

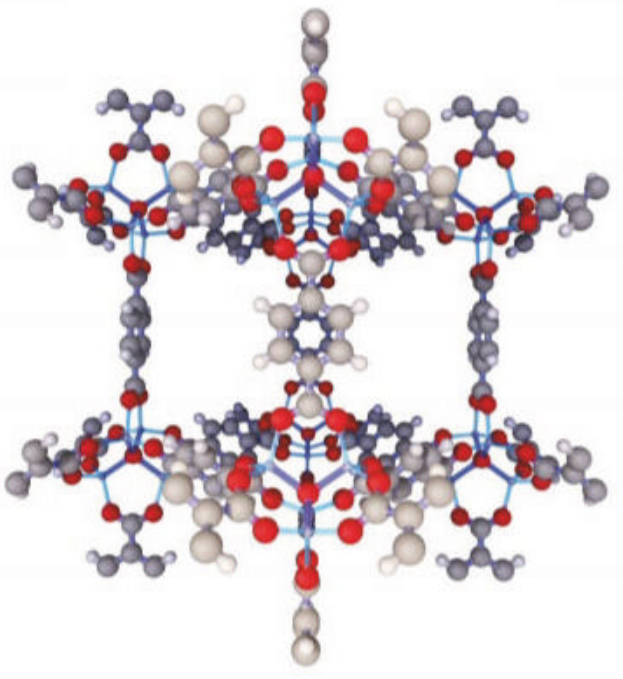
Chinda Virdee

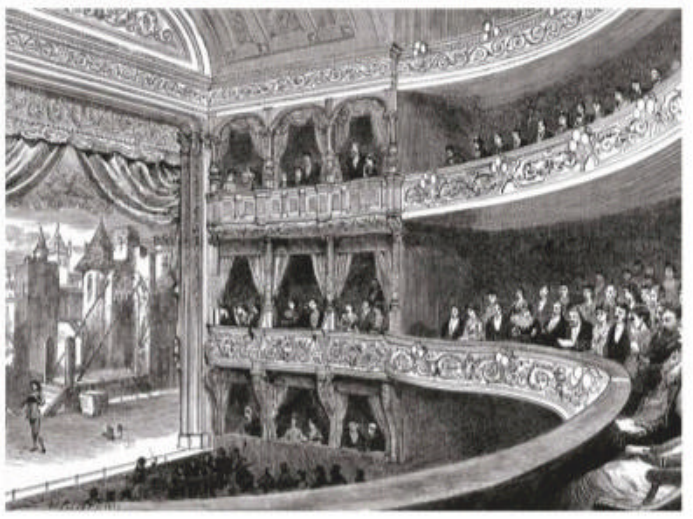
Colour is determined by the light that an object is able to reflect rather than absorb. As mirrors reflect every colour in the visible spectrum they are therefore white. However, unlike objects that we see as white, which reflect all colours in all directions – known as diffuse reflection – mirrors reflect colours back in a targeted way, known as specular reflection. Thus, a mirror is a special form of white. There's one more wrinkle to add here though, as most of the mirrors we make aren't perfect. Usually the materials leave a greenish tinge behind, so a basic mirror is at best a greenish off-white. **JH**

What are MOFs? (Metal-organic frameworks)

Daniel Jenkins

Metal-organic frameworks are a class of crystalline materials made by linking inorganic units to organic ones through a process known as reticular synthesis. The result of this process is a material that keeps an organised structure even on tiny scales. The materials are promising candidates for many applications, including the storage of hydrogen and methane fuel. **JH**





Is there a limit to how many people Earth's resources can support?

Ruby Light

Yes, it's known as Earth's carrying capacity, but the exact number is hard to estimate. A report from the United Nations published in 2012 puts the number at around 8 billion, but it depends on how much each of us consumes. **LM**

What was the first building to be lit entirely by electricity?

Ryan Briggs

London's Savoy Theatre was the first public building in the world to feature electric lighting throughout. It opened in 1881 and was fitted with 1,200 incandescent light bulbs created by inventor Joseph Swan. **JT**

Is it better to sleep on your back or your side?

Jane Smythe

■ It's generally thought that it's best to sleep on your back, as this keeps your spine in a neutral position, reduces heartburn and leads to fewer wrinkles (as your face isn't squashed into the pillow), but this does mean you're more likely to snore. However, some people are advised to sleep on their sides, such as pregnant women, for whom there may be blood circulation benefits, and those with breathing conditions, who may find their airways clearer. **TL**

Although sleeping on your back is thought to be better, most people sleep on their sides

Want answers?

Send your questions to...

How It Works magazine

@HowItWorksmag

@howitworks@futurenet.com

How does Gmail's Smart Compose (predictive email text) work?

Svetlana Valentina

■ Gmail's Smart Compose uses a few different artificial intelligence tools to suggest what the end of sentences are before you've finished typing them. Like other predictive text systems, it analyses the words you've typed already against a language model – which includes the probability of different words being used and how they'd fit into a sentence – to suggest the most likely words to follow. However, it also uses context to guess what the email you're writing is about by analysing the email's subject or the content of previous emails in a chain and then adapts its predictions accordingly to increase accuracy. **TL**

Which are the most popular breeds of dog for people to keep as pets?

Cassidy March

■ For many years the most popular breed of dog in the UK has been the Labrador retriever, but recently the French Bulldog has just started to overtake it in popularity. **TL**

Why do batteries need to be recycled separately?

Harrison Marsh

■ Around 85 per cent of the weight of a battery is metal, including steel, zinc, manganese and potassium. A further 15 per cent is paper and plastic. But in among the recyclable components there are dangerous chemicals like lead, cadmium and mercury. Recycling them takes specialist equipment, but it's worth the hassle. Lead and gypsum from car batteries can go on to power more cars; nickel from household batteries is useful for metal plating; and cobalt recovered from laptop batteries can become new electronics. **LM**

BOOK REVIEWS

The latest releases for curious minds

The Astronaut Selection Test Book

Do you have what it takes to get to space?

- Author: **Tim Peake and the ESA**
- Publisher: **Century**
- Price: **£20 (approx. $26)**
- Release date: **Out now**

Tim Peake is the UK's most famous astronaut, and with good reason. The space explorer, who spent over 185 days on the International Space Station from December 2015 to June 2016, beamed messages back to Earth, appeared on television and recorded video experiments in zero gravity to demonstrate its effects. He even ran the London Marathon, strapped to a treadmill, while flying miles above the surface of the Earth.

It's no surprise then that his *Astronaut Selection Test Book* is packed with fun insights, challenging puzzles and interesting facts. The meat of the book comes in the form of a series of puzzles and questions that can help aspiring astronauts prepare for the strenuous tests set by space agencies around the world. They start easy, but the difficulty ramps up with tasks that require you to memorise complex codes, recognise patterns and more. The book might appear to be aimed at younger readers at first glance, but when the tasks get really tough they're bound to get frustrated. It's probably best to save this for slightly older readers as it's sure to keep even adults busy for hours.

Interspersed with the puzzles, you'll also come across photos from Tim's own training, including shots of him in buoyancy tests, centrifuges and zero-gravity training. They take place in the 'Vomit Comet', an aircraft that flies up to 8,500 metres then nosedives at 45 degrees in freefall to give the passengers in the open padded cabin the feeling of zero gravity. It's inspiring stuff, and each photo page is packed with information about the real-world training astronauts must face before they can step onto the launchpad.

Outside of the questions and photos there's a ton of interesting information buried in these pages. Tim does a brilliant job of talking readers through various tests by referring to his own experiences, such as discussing why space agencies ask open-ended questions; they are designed to test applicants' psychology.

Towards the end of the book we start to look towards the future. The Mars mission that Tim talks about in the final pages is, of course, just fiction at this point. However, for some people reading this book (especially young adults) it could become a reality. Now that's exciting.

★★★★★

"It's packed with challenging puzzles and interesting facts"

Everything You Know About Planet Earth is Wrong

No, that doesn't mean the Earth's flat

- Author: **Matt Brown**
- Publisher: **Batsford**
- Price: **£9.99 / $12.95**
- Release date: **Out now**

Possessing the kind of title designed to prompt the response of 'Oh really?', the latest instalment in the *Everything You Know About...* series nonetheless posits an interesting proposition. In a time of growing awareness of humanity's increasingly detrimental impact on the natural landscape, should we take heed?

The answer is obviously yes, but this isn't solely a cautionary tale. From the nature of continents and the early pioneers to the seasons of the year and the exact difference between Great Britain and the UK (hand on heart, do you honestly know the answer to this one?), this is as much a fact purveyor as it is a mythbuster.

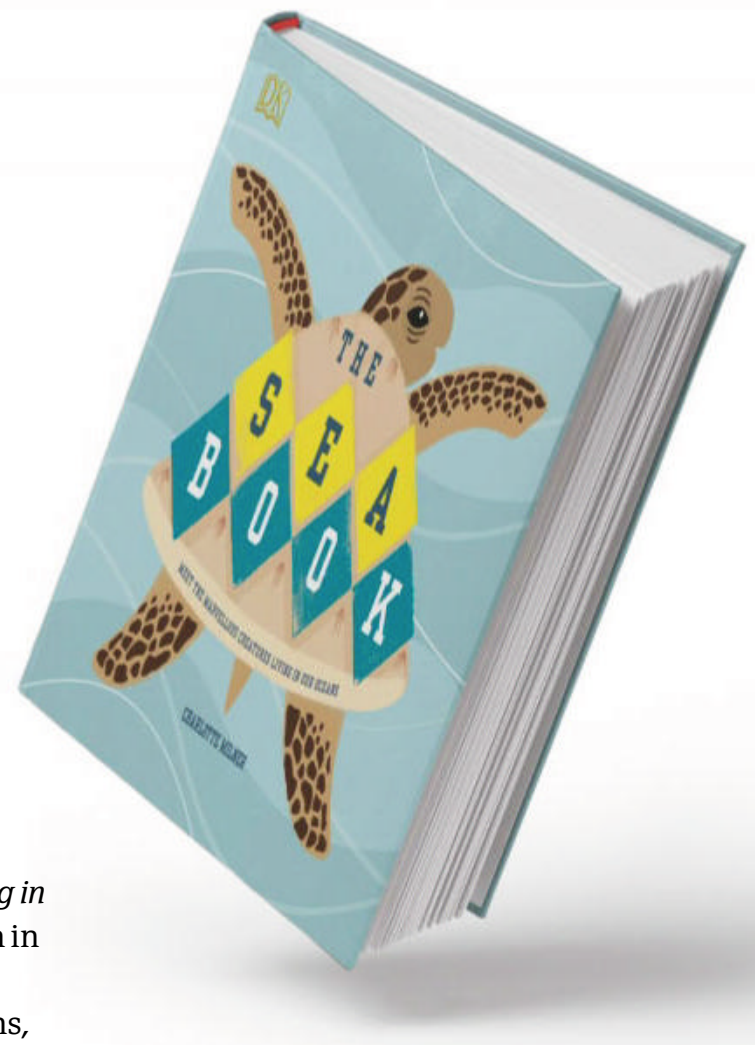
Presented in a style that will appeal to adults yet approachable enough for younger readers to decipher without too much trouble, this truly has cross-generational appeal and thus comes high on our recommendation list. You might want to check out the rest of the series too.

★★★★☆

The Sea Book

Down where it's better...

- Author: **Charlotte Milner**
- Publisher: **DK**
- Price: **£12.99 / $15.99**
- Release date: **Out now**



Subtitled *Meet the Marvellous Creatures Living in Our Oceans* (in case you were for some reason in any doubt about the subject matter), *The Sea Book* takes us on an odyssey across the oceans, covering habitats, its inhabitants and much more besides. It earns the title.

Aimed primarily at younger readers, every step of the journey is accompanied by bright, detail-packed illustrations underscoring the text and providing illumination to the subject matter. It's seemingly designed for those with short attention spans – it's a breeze to flick through and the actual word count isn't high, yet somehow it seems like less is more, with plenty being packed in.

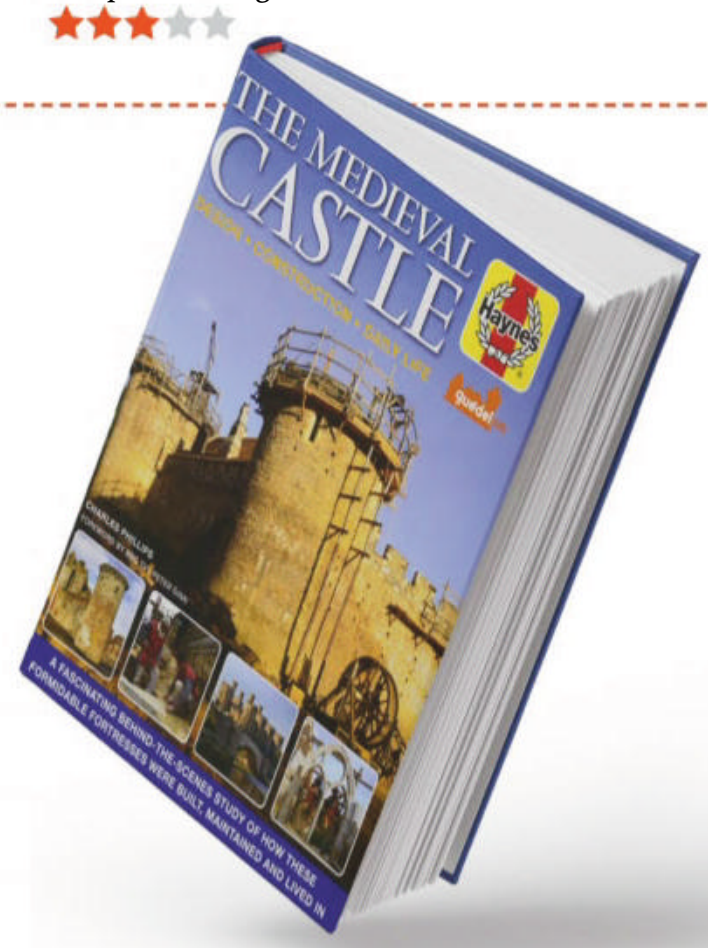
Since finishing it will likely be a swift process, it's worth questioning whether this is the right book to purchase for your young one. If you decide in the affirmative then you won't be let down; for a basic grounding in underwater life this provides a good start.

★★★☆☆

The Medieval Castle

Ruling the roost

- Author: **Charles Phillips**
- Publisher: **Haynes**
- Price: **£22.99 / $29.95**
- Release date: **Out now**



Castles are essentially Europe's pyramids. Built to last and withstand all manner of assaults, it's a testament to the ingenuity of the architects that so many of them remain as windows to the past long beyond the point of their strategic relevance. Regardless, they continue to be a source of awe and fascination to many, so it's not surprising that Haynes has decided to give their two cents on the subject.

Covering the construction process, the raw materials used, everyday life and much, much more, no stone has been left unmoved in Haynes' attempts to ascertain the secrets behind their grandeur, which is something we've come to expect from them. With Guédelon Castle in France as a case study, you will put down this book having discovered far more about these super-structures than you likely thought you ever would.

Combine these insights with Haynes' now trademark production values and you have something truly impressive indeed. We strongly suspect that your castle pilgrimage may begin very shortly...

★★★★★

End of the Megafauna

Giant-sized edition

- Author: **Ross D E MacPhee**
- Publisher: **W W Norton & Co**
- Price: **£25 / $35**
- Release date: **Out now**

When people talk about the 'good old days', it's usually the precursor to a recrimination-inducing discussion about political matters that most would rather leave unsaid. In the case of biologists, however, they may well be referring to an era when animals were truly massive – giant mammals, birds and the like.

End of the Megafauna gives us the chance to revisit this land before time, introducing us to bygone marvels like the Fijian crocodile and the Adams mammoth, along with birds weighing in excess of 800 pounds. Even lemurs were huge. Combining paleomammalogist Ross D E MacPhee's insight with illustrations by Peter Schouten, what was once extinct is brought vividly to life here.

Delving far deeper into the subject matter than anything you would have likely experienced before, this is a fascinating examination of a long-forgotten past and proof that giant life didn't end with the dinosaurs. A great gift for those who like their history with bite.

★★★★☆

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

A	E	P	R	C	Y	J	M	V	X	P	C	R	E	R
Q	A	E	S	H	I	R	E	M	V	O	P	L	T	A
W	M	A	E	I	Z	C	M	N	L	L	P	O	U	I
R	E	R	E	N	R	V	L	B	N	E	A	A	P	N
T	T	Y	E	O	P	I	L	O	O	S	X	M	O	F
B	E	X	S	O	R	E	T	R	N	X	C	B	L	O
M	O	V	U	K	I	U	E	Y	I	I	O	E	Y	R
U	R	B	T	I	M	G	W	O	T	O	N	R	M	E
S	I	W	O	X	A	T	P	C	R	P	U	G	E	S
C	T	O	L	U	D	X	R	J	X	E	M	R	R	T
L	E	P	O	X	I	A	Q	K	K	T	E	I	R	Z
E	V	V	B	T	D	A	W	V	A	V	G	S	H	Y
E	Q	T	W	N	I	X	B	X	E	E	L	A	H	W
W	C	H	I	C	X	U	L	U	B	X	M	U	T	P
A	N	T	A	R	C	T	I	C	A	B	C	E	R	O

FIND THE FOLLOWING WORDS...

AMBERGRIS
ANTARCTICA
ARCTIC
BEAK
CHICXULUB
CHINOOK
CLONING
LOTUS
MADIDI
METEORITE
MUSCLE
PEARY
POLES
POLYMER
RAINFOREST
SHIRE
VOYAGER
WHALE

Quickfire questions

Q1 Horses were first domesticated in modern-day _____

- Africa
- Australia
- Eurasia
- America

Q2 Vredefort crater is around ____ years old

- 2 million
- 2 billion
- 20 billion
- 200 million

Q3 What year was Antarctica discovered?

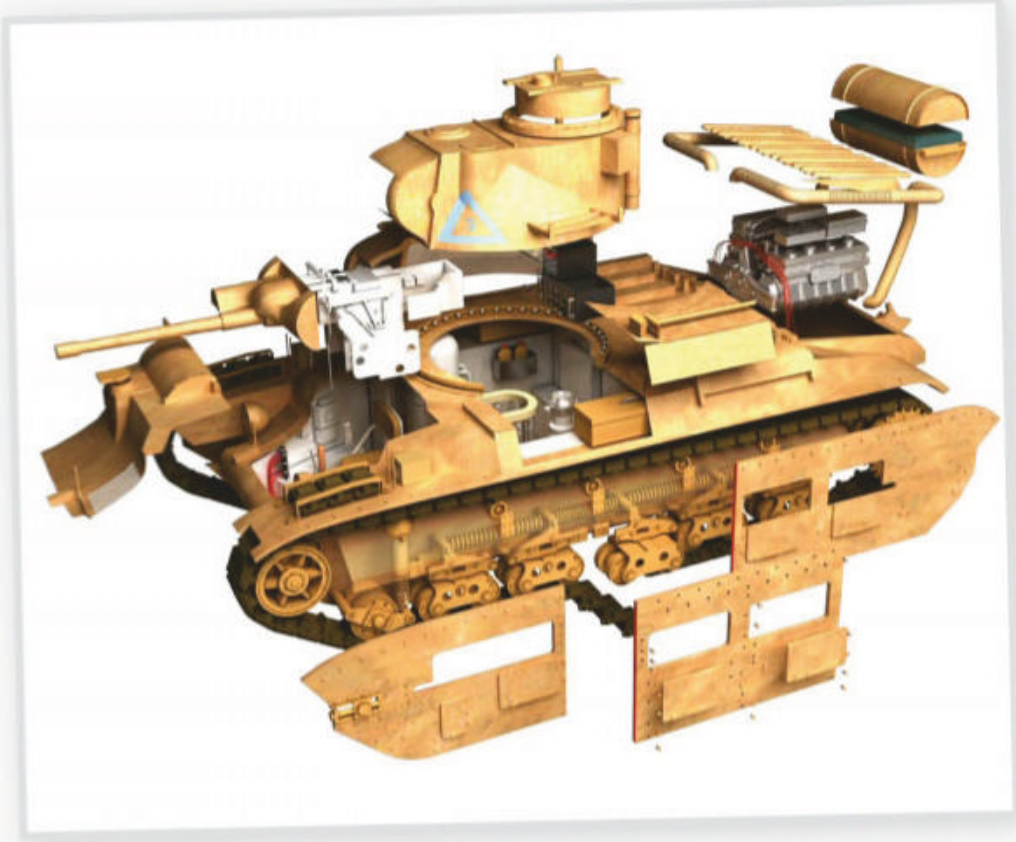
- 1780
- 1840
- 1880
- 1940

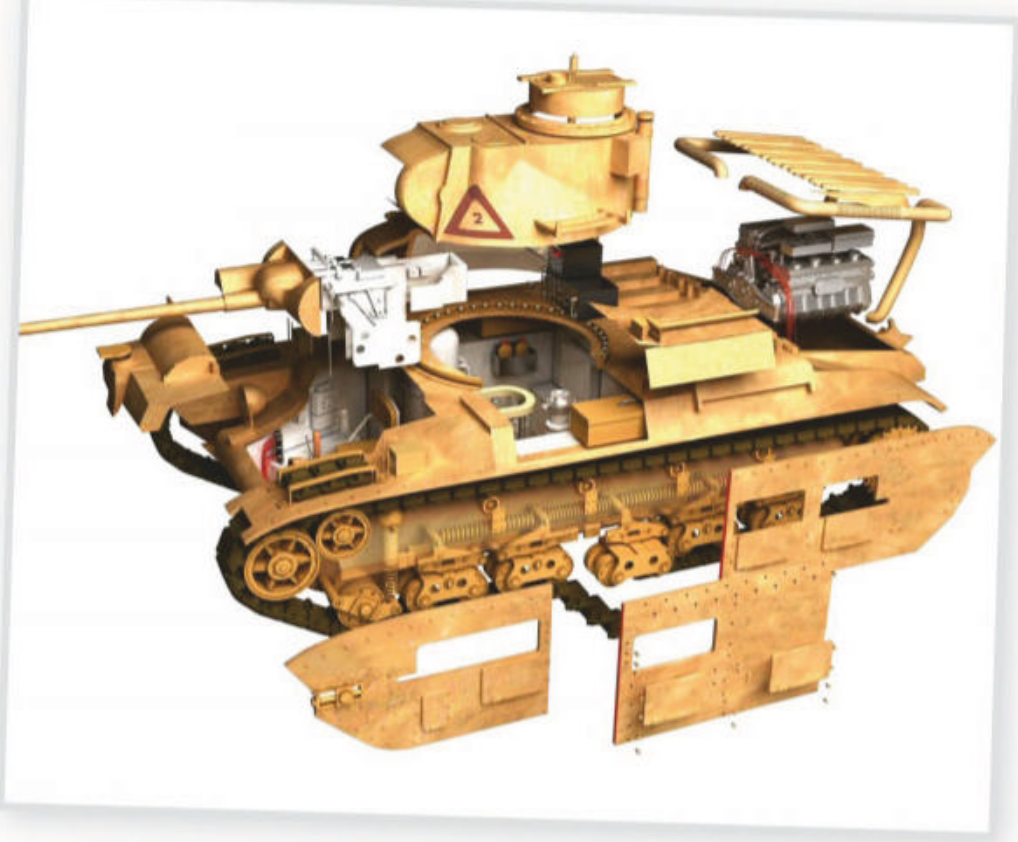
Q4 Name the famous sheep cloned in 1996.

- Dolly
- Dot
- Polly
- Pat

Spot the difference

See if you can find all six changes we've made to the image on the right





Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

4	2	9	5			8		1
5		3				6	7	2
7	6	1		8	3	4	5	9
	4	6			2	9	8	
	3		6	1			2	
2	9	7	4	5	8			3
	5	4	8		7		1	6
			3			2	9	7
	7		9	6	1		4	

DIFFICULT

2				1			8	9
			4				3	
		6						
8			9					2
	7	2	3		6			
			5		2		6	
				2		8		1
				9				3
	5	3			4			7

What is it?

Hint: You'll need to draw your own conclusion.

A .....

© Getty

Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 31 kilometres

Q2 Amur leopard

Q3 2001

Q4 -89.2° Celsius

What was it?

Geode

HOW TO...

Practical projects to try at home

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

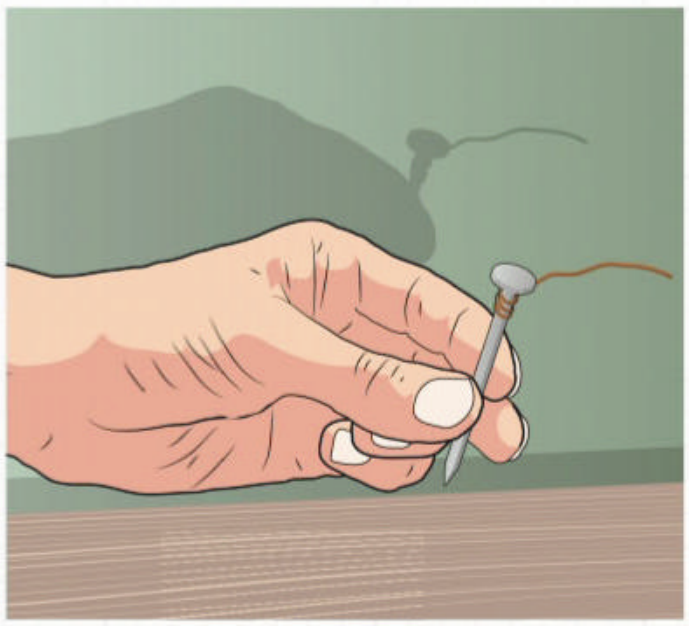
Get in touch

Send your ideas to...

How It Works magazine
@HowItWorksmag
@howitworks@futurenet.com

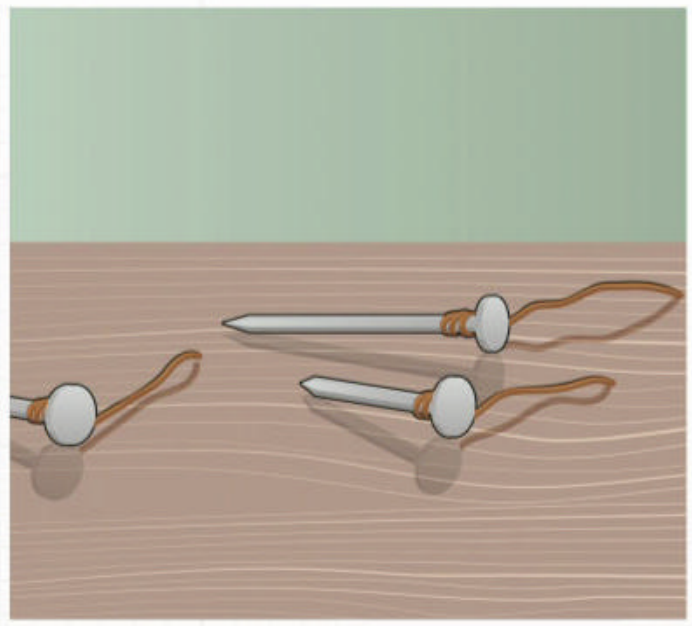
Make your own battery

Use some smart science and an ice cube tray to create a battery at home



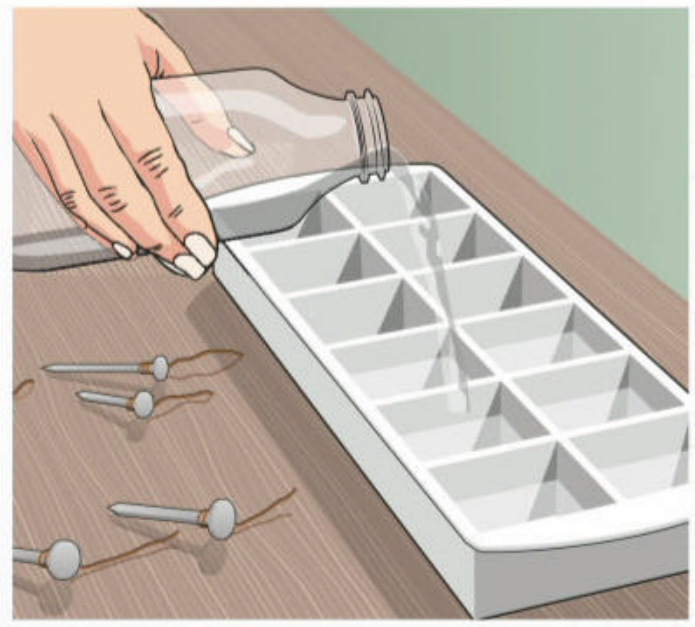
1 Wrap your nail

First, you need to find some galvanised nails (it's important that they're galvanised) and some copper wire. Wrap the copper wire around the nail five times near the head, leaving around eight centimetres of wire sticking out.



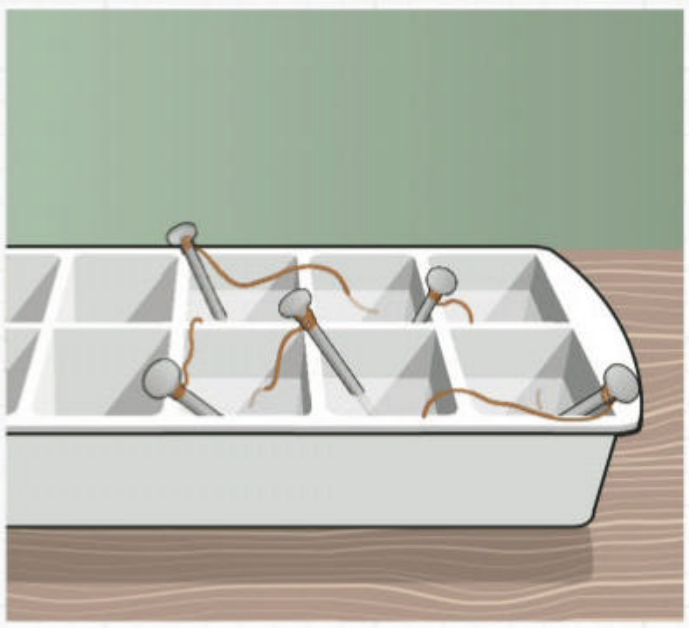
2 Get four more

Repeat the process above with four more nails so that you have five in total. You need a few to create the circuit – you can use more, but for now we'll manage with five. It should provide plenty of power for the LED.



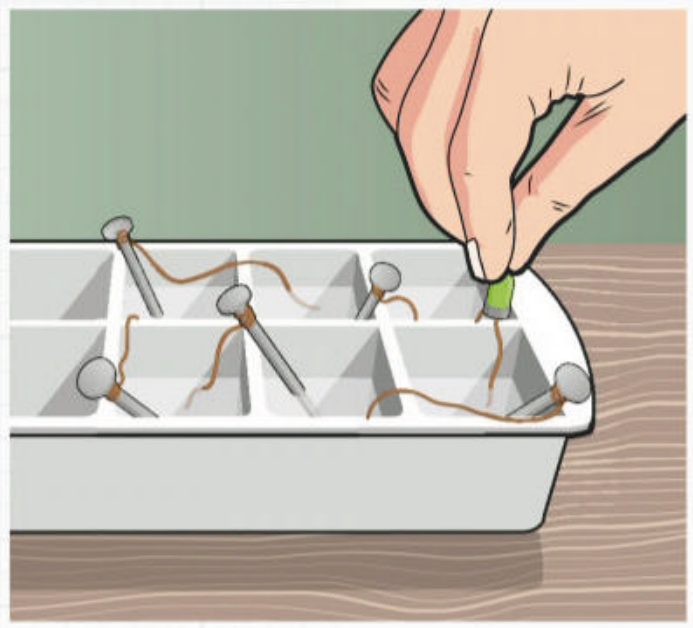
3 Fill your tray

Next you need to fill six adjacent sections of an ice cube tray with distilled white vinegar. They need to be next to each other so you can create a circuit, so make sure you use six in a pattern as we've shown here.



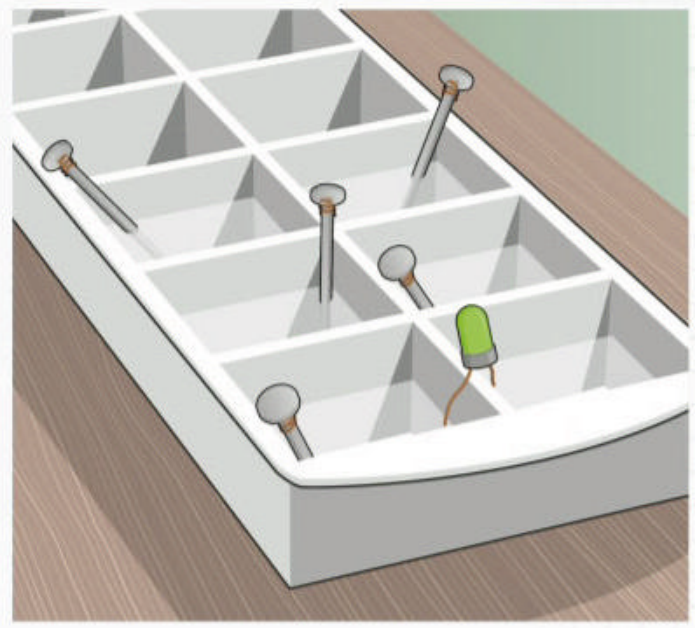
4 Place the nails in

Place the nails into the vinegar with the pointy ends in the liquid. Bend the wire so the loose end is submerged in the vinegar in the next section. Make sure it's not touching the other nail.



5 Add an LED

To test your circuit place an LED between the final two sections of the ice cube tray to complete the ring. The LED should light up, showing you that your circuit is complete and power is flowing.



6 Turn it around

If your LED didn't light, don't worry. Take it out, rotate it 180 degrees and put it back in with the two wires in the opposite sections to the ones they were in before.

SUMMARY...

Voltaic batteries work when metal electrodes and an acid help electrons flow. In this case the electrodes are in the zinc coating the nails and the copper in the wire. The acid in the vinegar helps them flow too, and because all of the sections in the tray are linked it creates a circuit. The electrons power the LED, so you can see it working.

Had a go? Let us know! If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

NEXT ISSUE

Create a light you can throw

WIN

URBANISTA BLUETOOTH HEADPHONES

This month we're giving away a pair of Urbanista New York Bluetooth headphones, which feature active noise cancellation and deliver up to 25 hours of play time.

For your chance to win answer the following question...

Which of the following is the world's largest impact crater?

a) **Chicxulub**

b) **Beaverhead**

c) **Vredefort crater**

Send your entries by email to **howitworks@futurenet.com** with the subject 'Competition' or write to us at:

How It Works,
Future Publishing,
33 Richmond Hill,
Bournemouth,
Dorset,
BH2 6EZ

© Urbanista

INBOX
Speak your mind...

Get in touch
If you have any questions or comments for us, send them to...

How It Works magazine | @HowItWorksmag | howitworks@futurenet.com

Letter of the Month

Now you see me, now you don't

Dear **HIW**,

I was recently reading a book, and the soldiers in it had special infiltration suits nicknamed 'chameleon suits'. They were suits that would change colour accordingly to match their surroundings and they contained their body heat so that they couldn't be found with infrared cameras. I was wondering if there actually are suits like these or are they just science fiction. Many thanks.

Shelby Bauman

Thanks for your question, Shelby, it sounds like an interesting book! As you can imagine, the military isn't big on divulging too much information about the technology they use in combat, however, that being said, a few pieces of technology have popped up over the years that suggest the potential for the creation of a 'chameleon suit'. For example, a material showcased to the world by camouflage creators HyperStealth back in 2012 was said to feature a nanotechnology material that would bend light, producing an invisible illusion known as 'quantum stealth'. The cape appeared as Harry Potter's invisible cloak did, however, the technology was not adopted by the US army as it was intended.

In more recent years a thermal camouflage material has been developed using graphene and electrical currents to reduce the infrared light emitted by the body and then detected by thermal cameras. Colour-changing fabric is another technology on the rise, also known a ChroMorphous. Woven like any other fabric, ChroMorphous threads can be activated by an electrical current to change its colour at the touch of a button. As this technology progresses we could see fabric that changes colour to match or blend in with its surroundings, just as a chameleon does.

Though this technology is being developed for the runway rather than the battleground, combining some of these camouflage technologies could potentially create a military must-have chameleon suit.

© Getty

WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
SCIENCE IS BEAUTIFUL: BOTANICAL LIFE
Discover a wonderful collection of microscopic photography exploring the beauty and science of plants in Colin Salter's visually appealing book.

Bronze or bust?

Hi **HIW**,

As I understand it, most statues from ancient Greece and Rome survive today in their Roman copies of Greek bronze originals. How did the Greeks sculpt in bronze?

Andreas Charalambous

Thanks for your question, Andreas. Originally, sheets of bronze were hammered in separate parts and joined using rivets. The Greeks eventually abandoned this method, replacing it with lost-wax casting. The most simple and earliest form of lost-wax casting involves sculpting a large statue out of solid wax. This was then coated with clay and heated, which allowed the wax to melt and the clay to harden. Next, the clay casing was filled with molten bronze and once the metal cools, the mould can be opened to reveal the bronze sculpture.

Bags after bedtime

Dear **HIW**,

Why do you get bags under your eyes after a bad sleep? I really hope you like my question.

Jamie Duncan, aged 11

There are many reasons we get bags/dark circles under our eyes. If someone wakes up with puffy bags this can be the result of eating too much salt before bed, causing the thin skin under their eyes to swell. Dark circles, however, are the blood vessels beneath the skin. When we don't get enough sleep our bodies release cortisol to increase blood flow and deliver more energy to the bodies muscles. The skin below the eyes appears darker due to the increased blood flow.

Sweet genetics

Dear **HIW**,

I was wondering, why can't scientists make healthy foods (e.g. vegetables) taste nice by changing their genes to make it taste like chocolate/sweets?

Elliot Jones

What a great idea, Elliot! However, in order to genetically modify vegetables you would need genetic information to insert or swap. Sadly, candy is mainly made up of artificial sugars. But the US' Grapery have developed varieties of flavoured grapes, including cotton candy grapes. These are not genetically modified, rather two other grape species cross pollinated to make them taste like cotton candy.

Winged rockets

Dear **HIW**,

We all know what a space rocket looks like: a tall, thin cylinder with thrusters at the base, but how is the rocket guided, as there are no wings for guidance?

John Metcalfe

That's an interesting thought, John. Airplanes require wings to generate a force called lift. This is utilised to offset the weight of the plane and lift it into the sky. However, the aim of a rocket isn't to stay in the sky but escape it. The cylindrical, pointed appearance of a rocket is designed to cut through the air on launch, reducing the effects of air resistance. When a rocket is sent to space, the desired direction of travel is directly straight and therefore there is no need for wings to navigate.

A rocket's shape is designed to cut through the sky and escape our planet as fast as it can

What's happening on... social media?

This month we asked you, if you could pick anyone throughout history to appear on a bank note, whom would you choose and why?

@lumberingbones
"Alan Turing, he doesn't get the recognition he deserves"

@Ellerichter
"Houdini - The notes will appear and disappear out of one's wallet frequently"

@StephenParry80
"Beatrice Hicks, the co-founder and first president of the Society of Women Engineers. Certainly on US banknotes"

@chiprocky
"Ada Lovelace who invented the computer. It takes a woman!"

@RobertoJones84
"Freddie Mercury, with Queen on the reverse side. For contribution to music naturally"

@andy_wedge
"John Lennon - one of our finest musicians whose legend lives on"

NEXT ISSUE...

Issue 123 on sale **21 MAR 2019**

Available in print from all good newsagents and **myfavouritemagazines.co.uk**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 44 (UK) and 83 (US).

HOW IT WORKS

Future PLC Richmond House, 33 Richmond Hill, Bournemouth, Dorset, BH2 6EZ

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Research Editor **Baljeet Panesar**
Production Editor **Charlie Ginger**
Staff Writer **Charlotte Evans**
Staff Writer **Scott Dutfield**
Editor-in-Chief **Gemma Lavender**

Contributors
Adrian Mann, Ed Crooks, Jackie Snowden, James Horton, Joanna Stass, Jodie Tyley, Jonathan O'Callaghan, Laura Mears, Nicholas Forder, Stephen Ashby, Steve Wright, The Art Agency, Tom Lean, Victoria Williams

Cover images
Getty; Apple; Urbanista

Photography
Alamy, Getty Images, NASA, Science Photo Library, Shutterstock, Thinkstock, Wikimedia
All copyrights and trademarks are recognised and respected

Advertising
Media packs are available on request
Commercial Director **Clare Dove**
clare.dove@futurenet.com
Group Advertising Director **Mark Wright**
mark.wright@futurenet.com
Advertising Manager **Toni Cole**
toni.cole@futurenet.com
01225 687368
Media Sales Executive **Jagdeep Maan**
jagdeep.maan@futurenet.com
01225 687353

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities
Head of Print Licensing Rachel Shaw **Rachel Shaw**
licensing@futurenet.com

Subscriptions
Email enquiries **contact@myfavouritemagazines.co.uk**
UK orderline & enquiries **0344 848 2852**
Overseas order line and enquiries **+44 (0)344 848 2852**
Online orders & enquiries **www.myfavouritemagazines.co.uk**
Head of subscriptions **Sharon Todd**

Circulation
Head of Newstrade **Tim Mathers**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Vivienne Calvert**

Management
Managing Director **Alastair Lewis**
Chief Content Officer **Aaron Asadi**
Commercial Finance Director **Dan Jotcham**
Editorial Director **Paul Newman**
Head of Art & Design **Greg Whittaker**

Printed by Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9001

ISSN 2041-7322

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill holds full FSC (Forest Stewardship Council) certification and accreditation

FAST FACTS

Amazing trivia to blow your mind

AMBERGRIS TURNS INTO A WHITE VAPOUR AT 100 DEGREES CELSIUS

70 BILLION

VALUE OF LEGITIMATE UK BANKNOTES IN CIRCULATION

2,152 METRES

THE DEPTH OF AN EXPLORATORY HOLE RECENTLY DRILLED IN ANTARCTIC ICE

18,958 SQUARE KILOMETRES

THE SIZE OF BOLIVIA'S MADIDI NATIONAL PARK

87.7 YEARS

THE HALF-LIFE OF PLUTONIUM-238, THE ELEMENT USED IN SOME SPACE PROBES

29 TONS

IN 1924, A SINGLE SHIRE HORSE PULLED THIS HEFTY LOAD

1998

THE YEAR SOUTH KOREAN SCIENTISTS CLAIMED TO HAVE CLONED A HUMAN EMBRYO

2013'S CHELYABINSK METEOR EXPLODED WITH THE POWER OF AROUND 30 HIROSHIMA BOMBS

THE SWORD-BILLED HUMMINGBIRD (ENSIFERA ENSIFERA) IS THE ONLY BIRD THAT HAS A BEAK WHICH IS LONGER THAN ITS BODY.

12 SECONDS PER YEAR

THE ACCURACY OF OMEGA'S 1974 QUARTZ MARINE CHRONOMETER WATCH

7,600 THE NUMBER OF HEART TRANSPLANTS CARRIED OUT WORLDWIDE IN 2017

PUT A PAUSE IN YOUR DAY

With so many demands from work, home and family, there never seem to be enough hours in the day for you. Why not press pause once in a while, curl up with your favourite magazine and put a little oasis of 'you' in your day.

PRESS PAUSE
ENJOY A MAGAZINE MOMENT

To find out more about Press Pause, visit;

pauseyourday.co.uk

POWERBALL® GYROSCOPES

DEVELOP YOUR OWN GRAVITATIONAL FORCES...LIKE TINY SPINNING PLANETS

280 Classic
The Entry One

280 Autostart Classic
The All Round One

Diablo Evo Autostart
The Muscle One

280 Autostart Pro
The Best Selling One

Titan
The Most Powerful One

280 Autostart Fusion
The Amazing One

amazon

Over one thousand
5-star reviews

powerballs.com

A zero gravitational training aid for NASA astronauts, Powerball® develops over 60 times its own weight in gyroscopic resistance and delivers strengthening and rehabilitation for the arms & wrists unlike anything else on *(or off)* this planet.